SONS OF THE EARTH

BY

Kirtley F. Mather

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Sons of the Earth

SONS OF THE EARTH

The Geologist's View of History

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IN
HARVARD UNIVERSITY

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TO THAT

UNKNOWN ANCESTOR OF MINE

who first considered the moral consequences
of his own conduct
and thus having partaken of the fruit
of the tree of knowledge of good and evil
was promoted
from a paradise of contentment into
a world of problems.

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Table of Contents

Preface	xiii
Chapter 1: *Mother Earth's Diary*	3
Chapter 2: *The Stream of Life*	36
Chapter 3: *The Family Tree of the Higher Vertebrates*	74
Chapter 4: *Man's Ancestral Lineage*	101
Chapter 5: *Artists and Artisans of the Great Ice Age*	134
Chapter 6: *The First Families of America*	170
Chapter 7: *The Heritage from Mother Earth*	206
Chapter 8: *The Outlook for the Future*	239
Bibliography	264
Index	269

List of Illustrations

PLATE I : *The Grand Canyon of the Colorado, from Cape Royal on the North Rim* 16

PLATE II : *The Green River formation, northwestern Colorado — Polished surface of varved marlstone from the Green River formation* 48

PLATE III : *A fossil ichthyosaur — A dinosaur "quarry" in Wyoming* 80

PLATE IV : *Gibbon — Orang-utan — Chimpanzee — Gorilla* 112

PLATE V : *The late Tertiary ancestors of mankind — A Neandertal workshop* 144

PLATE VI : *Notharctus, one of the oldest known fossil primates — Cranium of Sinanthropus pekinensis, found Dec. 2, 1929* 176

PLATE VII : *Restoration of Pithecanthropus erectus — Restoration of Eoanthropus dawsoni — Restoration of Homo neandertalensis — Restoration of Cro-Magnon man* 208

PLATE VIII: *A paleolithic hunt — A Cro-Magnon artist working in a Dordogne cave* 240

List of Illustrations

1. *Ausable Chasm, Adirondack Mountains, New York* 5
2. *An anticline in the Canadian Rocky Mountains* 6
3. *Heaven's Fold, Montana* 7
4. *A wave-cut platform on the coast of Scotland* 8
5. *"Unconformity" in the Box Canyon, Ouray, Colorado,* 10
6. *The radio-active timekeepers* 14
7. *Map of New England, showing the principal glacial features* 23
8. *The geologist's time- table* 31
9. *An early Paleozoic trilobite* 45
10. *A middle Paleozoic ostracoderm* 47
11. *A Devonian armored fish* 48
12. *The evolution of the vertebrate leg from the fin of a fish* 53
13. *Plesiosaur paddles* 55
14. *A primitive amphibian and its environment in late Paleozoic time* 57
15. *One of the largest of the herbivorous dinosaurs* 58
16. *Triceratops, an armored herbivorous dinosaur* 60
17. *Infant dinosaurs hatching from eggs* 61
18. *One of the pterosaurs, or flying reptiles* 62
19. *Restoration of archeopteryx, the oldest known bird* 63
20. *Nature's three types of wing structure* 64

21. *An imaginative concept of the spirit of Cretaceous time* 68
22. *Skulls of mammal-like reptiles and a primitive mammal* 69
23. *Mammalian jaws from Mesozoic rocks* 70
24. *Placental mammals from the Cretaceous of Mongolia* 71
25. *The pen-tailed tree-shrew* 72
26. *Unconformities in the Grand Canyon of the Colorado River* 75
27. *Badlands of South Dakota* 79
28. *Eohippus, the oldest known member of the horse family* 81
29. *Spectral tarsier* 82
30. *Lemur* 84
31. *Four primate skulls* 88
32. *The family tree of the primates* 94
33. *The Taungs skull* 96
34. *Primate feet* 99
35. *Europe during the Great Ice Age* 103
36. *The northeastern states during the Great Ice Age* 104
37. *Correlation of glacial stages in Europe and North America* 106
38. *Human remains from Piltdown, England* 110
39. *The Piltdown jaw compared with that of a chimpanzee and of modern man* 113
40. *The Piltdown skull compared with that of an ape and of man* 115

41. *Flint artifacts from Piltdown, Sussex, England* 116
42. *Fossils from Trinil, Java* 117
43. *Restoration of Trinil skull* 118
44. *Cast of interior of Trinil skull compared with brain of gorilla and of man* 120
45. *Restoration of Pithecanthropus erectus* 122
46. *The Rhodesian skull* 127
47. *Pelvis of Rhodesian "man"* 128
48. *The Heidelberg jaw compared with that of a chimpanzee and of modern man* 130
49. *Evolution of the hand* 137
50. *Gorilla* 139
51. *Eolith and method of using it* 141
52. *Eoliths, unmistakable and doubtful* 143
53. *Le Grand-Roc, Dordogne, France* 145
54. *Laugerie-Basse, Dordogne, France* 147
55. *Pre-Chellean paleolith* 149
56. *Chellean cleaver* 150
57. *Quartzite hammerstone* 151
58. *Acheulian cleaver* 152
59. *Acheulian axe and possible method of mounting it* 153
60. *Mousterian artifacts* 154
61. *Aurignacian artifacts* 155
62. *Solutrean blades and points* 156
63. *Magdalenian artifacts* 157
64. *Magdalenian harpoons* 158
65. *Table of paleolithic stages* 161
66. *Aurignacian drawing of a mammoth* 163

67. *Paleolithic drawing of a rhinoceros* 164
68. *Engraving of hairy mammoth from Les Combarelles* 165
69. *Paleolithic drawing of a horse* 166
70. *Paleolithic painting, the stag hunt* 167
71. *Serpent Mound, Ohio* 175
72. *Mounds near Newark, Ohio* 177
73. *Village of Walpi, Arizona* 180
74. *Balcony House, Mesa Verde National Park, Colorado* 181
75. *Cliff Palace, Mesa Verde National Park, Colorado* 182
76. *Cliffdwellings in Walnut Canyon, Arizona* 184
77. *Restoration of the hieroglyphic stairway at Copan* 188
78. *Map, showing the geographic distribution of modern man* 193
79. *Glacial and interglacial deposits in the Don Valley, Ontario* 195
80. *Artifacts from Folsom, New Mexico* 202
81. *The "fin-back lizard" of late Paleozoic time* 225
82. *Areosceles, an agile reptile of the late Paleozoic* 227
83. *Mesosaurus, an aquatic reptile of the late Paleozoic* 229

Preface

To UNDERSTAND himself, is man's most pressing need. Such understanding can come only through the synthesis of all available knowledge gained by observation, introspection and retrospection. No single approach to the problem can possibly enable us to see ourselves in true perspective, much less to comprehend the true character and real possibilities of human nature. But the point of view of the geologist is, to say the least, an excellent point from which to start the synthetic survey. For that point of view enables one to see not only the long vista of earth history, with its dramatic pageant of organic evolution, but also directs attention to the intimate relation between man and the manifold resources provided by his earthly environment. An understanding of man's place in nature is certainly prerequisite to the understanding of the nature of man. With that thought in mind, I have attempted here to present some of the facts and theories of modern geological science in non-technical language, with the hope that they may prove of interest as well as value to readers who have not previously been trained in the lore of the earth.

The substance of the eight chapters of this book was first presented as a series of eight lectures under the general title, "The Geologic History of Mankind," at the Lowell Institute in Boston during March, 1930. My hearty thanks are due to President A. Lawrence Lowell and his associates

in that organization, not only for the opportunity thus afforded of reaching a large non-academic audience, but also for the stimulus thus provided for organizing the material in its present form.

I am also under deep obligation to many fellow scientists and friends for assistance which they have given me in various ways. Only a few of the many to whom I should like to make grateful acknowledgement may be mentioned here. The days which I spent in 1928 with Dr. George Grant MacCurdy in the Dordogne region in France were unusually fruitful ones for me, because of his expert guidance among the remarkable pre-historic relics of that area. Dr. George B. Cressey, until recently Professor of Geology in Shanghai College, Shanghai, China, has kept me informed concerning the important discoveries of pre-human remains, which have been made in that country during the last few years. From my Harvard colleague, Dr. Percy E. Raymond, I have repeatedly received wise counsel concerning details of the paleontologic record and material suitable for illustrative purposes. My secretary, Miss Marian L. Drisko, made the stenographic transcript of the lectures given at the Lowell Institute and has rendered efficient service in preparing the manuscript for publication. My wife has aided materially in the revision of the lectures to make them more suitable for the new audience of readers, and in many other ways has assisted me in this particular piece of work.

For the most part, acknowledgment of indebtedness incurred in connection with the illustrations is made in the descriptions of the various plates and figures, but special mention should be given of the courtesies extended by Dr. William K. Gregory and Pres. Henry Fairfield Osborn of

the American Museum of Natural History, Professor Charles W. Brown of Brown University, Dr. W. C. Mendenhall and Mr. W. H. Bradley of the United States Geological Survey, Director George L. Collie of the Logan Museum at Beloit College, Mr. Harold J. Cook of the Colorado Museum of Natural History, Dean Homer P. Little of Clark University, Dr. Robert M. Yerkes of the Institute of Human Relations in Yale University, Mr. C. J. Collins of the Union Pacific Railroad Company, Mr. H. R. Mitchell of the New York Zoological Park, the Macmillan Company, publishers of Wilder's "Man's Prehistoric Past," D. Appleton and Company, publishers of MacCurdy's "Human Origins," G. P. Putnam's Sons, publishers of Gregory's "Our Face from Fish to Man," the American Philosophical Society, publishers of Gregory's "The Upright Posture of Man," and the University of Chicago Press, publishers of Williston's "Water Reptiles of the Past and Present."

Greatest of all, and most obvious to the reader, is my indebtedness to Edward A. Schmitz who has prepared the many pen-and-ink sketches which enliven and clarify the text. His artistic skill and expert technique are at once apparent, and his contribution to the volume speaks for itself.

KIRTLEY F. MATHER

Cambridge, Mass.
August, 1930

Sons of the Earth

The Geologist's View of History

Chapter 1

Mother Earth's Diary

> *"And some rin up hill and down dale, knapping the chucky stanes to pieces wi' hammers, like sae mony road-makers run daft. They say 'tis to see how the warld was made!"*
>
> SIR WALTER SCOTT IN ST. RONAN'S WELL

Geologists are trying "to see how the warld was made," because they believe that such knowledge will prove of great value to mankind. It is not simply a question of satisfying the natural curiosity of the human mind. Knowledge of the past, coupled with understanding of the present, provides the only key which man has ever found to be trustworthy in his attempt to unlock the future. Man is so completely "child of the earth," his past life has been so dominantly influenced by his geographic environment, and his present condition is so significantly dependent upon the terrestrial resources, that it is not an exaggeration to say that the only real hope for his continued success or future prosperity as an inhabitant

of this planet depends upon his ability to discover accurately the facts of earth history. The salvation of the human race is involved in the attempt to ascertain and interpret the events and forces which have contributed to the development of mankind from pre-human ancestors and the utilization, as yet incomplete, of the resources available in and upon the earth.

Hidden in the rocks of the earth's crust are countless vestiges of creation, the record of the progress which life has made as it has moved along the road stretching from its unknown beginning onward to the present day. Indeed, the very rocks themselves are the pages of a great book, Mother Earth's diary, which when properly related to each other and correctly interpreted tell us much concerning the history of the earth and its inhabitants. The interpretation of this record involves the determination of the sequence of events during which the rocks themselves were formed.

At many places the outer shell of the solid earth consists of sedimentary rocks such as sandstone, shale and limestone. These were at one time layers of sediment collecting on the floor of sea or lake or spread by streams over the surface of the land. Layers of sand have been cemented into beds of sandstone; the mud has been compacted into shale; and deposits of limey sediment have been consolidated into limestone. Over large areas of the earth's surface, such rocks have remained practically undisturbed and therefore

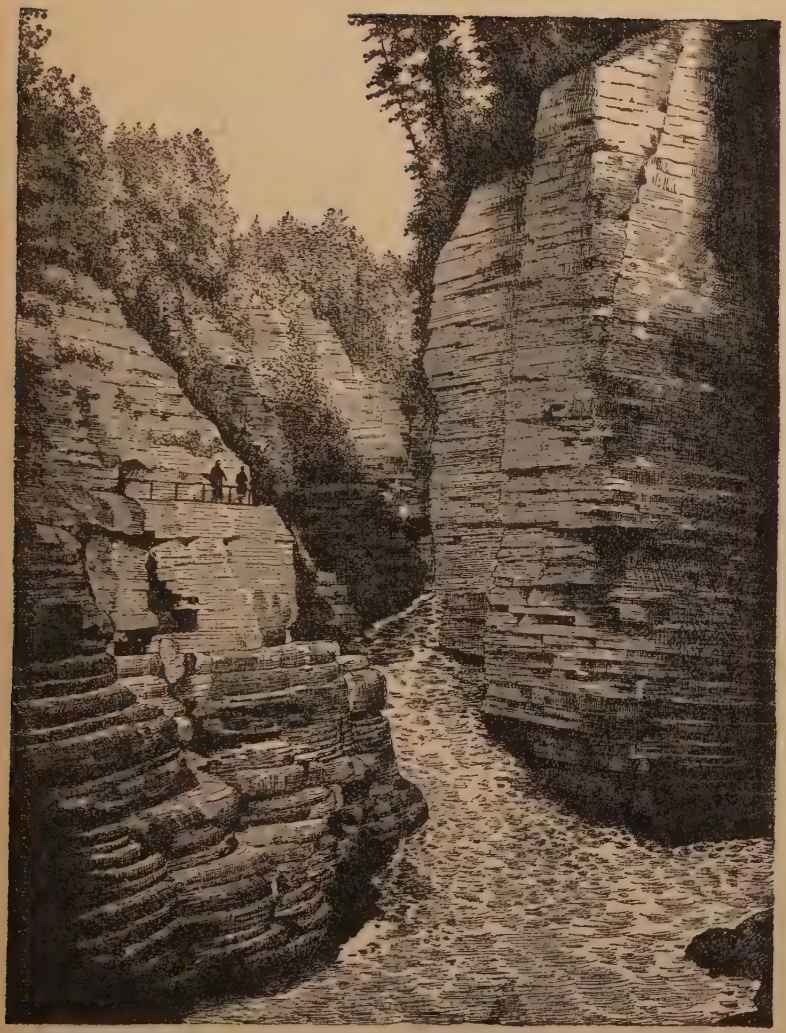

FIGURE 1. *In the steep walls of Ausable Chasm, on the northwest side of the Adirondack Mountains, the successive layers of sandstone are exposed in their original attitude; the oldest beds are at the bottom of the gorge, the youngest at the top.*

in their initial position. Their horizontal layers are today in the same order in which they were originally formed. Where exposed on abrupt hillsides or along the slopes of steep-walled valleys, such as Ausable Chasm or the Grand Canyon of the Colorado, it is obvious that the uppermost beds are the youngest

FIGURE 2. *At many places, as here in the Canadian Rocky Mountains, the stratified rocks have been folded by lateral compression during a mountain-making episode. Such an arch is known as an anticline.*

and the lowermost are the oldest. As one descends from the brink of such a chasm toward the rushing stream at the bottom of the abyss, one is moving progressively backward in time.

In certain places, the sedimentary rocks are more or less disturbed from their original attitudes. In the Appalachian Mountains, as in most mountain ranges, they are bent and twisted, so that they now appear

in great arches or troughs which may or may not conform to the present system of valleys and ridges. As a rule the master streams in the Appalachians have cut their channels directly across the folded strata and the steeply inclined or regularly arched layers are well exposed along the valley walls. Obviously,

FIGURE 3. *Heaven's Fold, in the Montana Rockies, is an excellent illustration of the deformation which originally horizontal layers of sedimentary rocks may undergo, when a large segment of the earth's crust is compressed as though it were caught between the closing jaws of a gigantic vice.*

the folding of these rocks was an event which occurred subsequent to the deposition of the youngest bed involved in the disturbance.

At a few localities, as along the coast of Scotland, the formerly horizontal layers of sedimentary rocks are now in a vertical position or even overturned. Under such conditions it becomes necessary

FIGURE 4. *If the vertical beds near the middle of Figure 3 were bevelled by wave erosion, they would appear like these rocks on the coast of Scotland. The parallel lines, which extend from beneath the sand in the foreground to the surf in the distance, are the edges of the bedding planes of stratified rock, long ago upturned into a vertical position. If one can ascertain which is top and which bottom of any single layer of rock, he can tell whether the older rocks are at the right or the left of the view.*
(SKETCHED FROM PHOTOGRAPH BY GEOLOGICAL SURVEY OF SCOTLAND.)

to discover which is the original top and which the original bottom of the layers themselves before one may determine which are the older and which the younger strata. This discovery is frequently made possible by noting the marks upon the bedding surfaces, such as ripples left by undertow or other currents in sea or lake, or tracks and trails of animals that crawled or squirmed along the wet sand or mud before it became solid rock. The preservation of such intimate details in the early history of the sediments often provides the clue which is needed as the basis of historical geology.

Where upturned or overturned strata have been bevelled by wave erosion or the wear of running water, they may subsequently be buried beneath a veneer of younger sediments. Thus in the Box Canyon near Ouray, Colorado, there is an excellent exposure of flat-lying sedimentary rocks resting upon the bevelled edges of a vertical series. Obviously, the upper system of rocks must be very much younger than the lower one. After the lower series had accumulated as flat layers on an ancient basin floor it must have been elevated and upturned during an episode of crustal crumpling. Then erosion bevelled the land and formed the horizontal surface which later was submerged beneath the sea and buried beneath the sand and limey ooze which consolidated to form the upper series. All this must have required a long period of time and the conclusion is inescapable that the two groups of strata are of very different age.

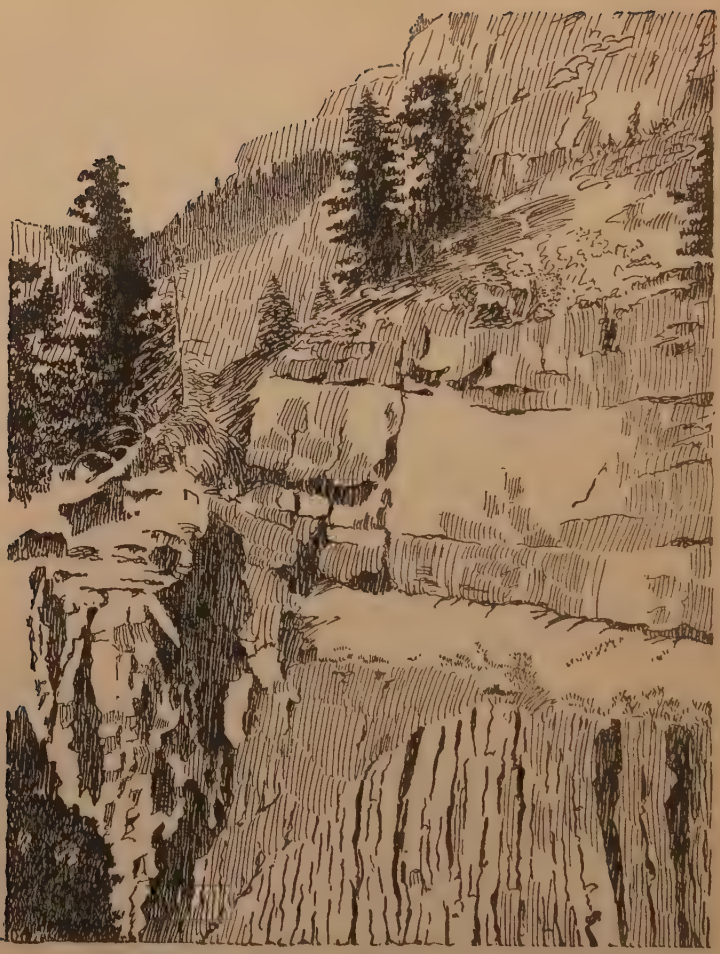

FIGURE 5. *The "unconformity" displayed on the sheer wall of the Box Canyon near Ouray, Colorado, is the result of a long chain of geologic events. After the rocks in the lower part of the view had been deposited, upturned and eroded, as in Figure 4, another series of rocks was deposited upon them, even as sand and mud are now accumulating beyond low-tide line on the wave-cut platform along the coast of Scotland. These upper, flat-lying beds are therefore much younger than the lower, vertical beds on which they rest.*

By drawing such deductions as this from the physical relations of the several rock masses we are able to discover the sequence of events in the geologic history of the earth. When the fragments of historical data from many localities are pieced together, the geologist finds that it has been customary in the past development of the earth for long periods of quiet accumulation of sedimentary rocks to be terminated more or less abruptly by disturbances of the earth's crust. These involve the crumpling of mountain ranges, the intrusion and extrusion of molten lava, the sinking of lands beneath the sea, and the elevation of shallow sea floors to form new lands. Such crustal movements are the milestones in the history of the earth. In North America the most conspicuous of these milestones celebrate the crumpling of the Appalachian Mountains, the uplift of the Sierra Nevada and the birth of the Rocky Mountains. These occurred in the order named and each was separated from the others by long intervals of comparative stability of the earth's crust. The relative date of each mountain-making disturbance is necessarily more recent than the formation of the youngest rocks which were involved in the crustal movements, and is older than the oldest rocks deposited after the movements had ceased. Such relations can be ascertained solely from the physical positions of the various strata.

Occasionally a mountain-making disturbance involves the overthrusting of one section of the

earth's crust upon an adjacent area. Where this happens the relative position of the strata does not immediately indicate the sequence of events, because older rocks may thus be superimposed upon younger ones. Or again, the folding of the crust may result in the complete overturning of the layers of which it is composed; and in this way the older beds may appear on top of the younger ones. An excellent illustration of the first mentioned condition is found along the eastern front of the Rocky Mountains in northern Montana and southern Canada, whereas overturned folds may be observed at many places in the Alps. Critical examination of such localities is therefore necessary before the chapter in earth history, which they record, can be correctly interpreted. But as a rule the fracturing and overthrusting of the rocks is readily apparent even though the layers above and below the plane of movement may at some places be parallel to each other. Certainly, experience has completely vindicated the belief of the geologist that it is possible to ascertain from the rocks themselves the sequence of events which brought them into existence and gave them their present form and position.

Having thus ascertained the relative dates of the many episodes involved in the physical history of the continents, it is highly desirable to discover the actual lapse of time intervening between successive important events. When the geologist is asked to tell the age of the earth or of a particular fossil or of man

himself, the questioner usually expects an answer phrased in terms of years. Consequently various attempts have been made from time to time to find a geological timepiece. Most of such attempts have proved very unsatisfactory, either because of their inaccuracy, due to the irregular speed of the process considered, or because of the failure of the method to give sufficiently precise measures of time. Recently, however, the physicists have provided us with a fairly accurate timepiece which may be used for those rocks in which the minerals contain radio-active elements such as uranium or thorium.

Radio-activity is the spontaneous decomposition of complex atoms. Radio-active substances are constantly emitting invisible radiation, known as alpha, beta and gamma rays. Alpha rays are electrically charged atoms of helium; beta rays are electrons, fundamental units of which atoms are constructed; and gamma rays are not material particles but quanta of energy of the same nature as x-rays. All are shot out explosively like bullets from a gun. Necessarily the ejection of these portions of an atom changes materially the constitution of the substance from which they are ejected. The dream of the alchemists of the Middle Ages is at last known to be realized. One element is transmuted into another. But, alas, the product is not gold but lead. Moreover, man has no control over the process. When the atomic gun gets ready to fire, the projectiles are exploded at velocities of many thousands of miles per second. Man has

not yet learned how to pull the trigger; no change which he has been able to produce in the environment of the atom can either hasten or retard the explosion. Apparently, the rate of decomposition is quite independent of external conditions; it may therefore be safely assumed to have been precisely the same during the history of the earth since the planet attained its present mass and state.

THE RADIO-ACTIVE TIMEKEEPERS

1 GRAM URANIUM GENERATES 1cc HELIUM IN 9 000 000 YEARS.

U	=	Pb	+	8He	+	ENERGY
URANIUM		LEAD		HELIUM		
238.2		206		8 X 4 = 32		0.2

1,000,000 GRAMS URANIUM YIELD $\frac{1}{7400}$ GRAM LEAD PER YEAR.

AGE OF MINERAL = $\frac{Pb}{U}$ X 7,400 MILLION YEARS.

FIGURE 6. *Radio-activity makes possible an accurate measurement of geologic time.*

Uranium, the most complex atom known in the physical universe, is the starting point of a long series of radio-active substances which are formed each in turn as decomposition occurs. When one atom of uranium has discharged three atoms of helium, the uranium has become radium. It in turn emits alpha, beta and gamma radiation at an even more rapid rate, and after five more atoms of helium have been shot out from each atom of radium the residue is lead. This is quite stable and apparently is the final

end-product of the radio-active series. Uranium is constantly breaking down into helium and lead, as the energy within its complex structure is liberated in the form of beta and gamma rays. The radio-active timepiece may therefore be likened not to a clock which "records time in ticks that are heard and pass away" but rather to an hour-glass in which the accumulating materials are helium and lead. Helium is a gas and quite capable of escaping into the atmosphere or through it into space, but lead is an inert solid and remains where formed unless chemically attacked or physically transported elsewhere. If we can ascertain the rate at which lead is formed from uranium and the relative amounts of the two substances in an undisturbed mineral which originally contained only uranium, we can compute the length of time during which spontaneous decomposition has been continuing.

Careful observations have revealed the fact that a gram of uranium generates helium at the rate of one cubic centimeter in nine million years. Knowing that eight atoms of helium must be released from one atom of uranium in order to transform it into an atom of lead, we may compare the atomic weights of the three elements and conclude "that 238.2 parts of uranium produce 206 parts of lead in the same time as 32 parts of helium." Putting all these facts together, it follows that "a million grams of uranium give rise to 1/7400 of a gram of lead every year."

This provides us with a simple formula which

gives a first approximation to the age of any mineral in which the amount of uranium and of lead derived from uranium can be determined by analysis. The percentage of that lead to the uranium from which it came is multiplied by 7,400 million years to give its age.

The figures thus obtained are surprisingly large. One of the oldest known uranium-lead-bearing minerals is from the oldest rocks in Australia and dates back 1,260 million years. Similar figures are derived from the analysis of rocks in Canada, which the geologist has long believed to be of almost equivalent age to those in Australia to which reference has just been made. Probably the recorded history of the earth covers approximately one and a half billion years.

The radio-active timekeepers have been abundantly vindicated in the last few years. In the first place, the order of the rocks as indicated by this method duplicates the sequence as determined by their positions with respect to each other. The two methods of determining relative age are wholly independent of each other, and yet they yield identical results so far as the order of events is concerned. Thus our confidence in the accuracy of each method is greatly strengthened.

PLATE I: *The Grand Canyon of the Colorado River is an "abyss of time." Descending its precipitous walls, one steps upon successively older layers of the flat-lying rocks which form the Colorado Plateau. These pages in Mother Earth's diary are well displayed in this view from the North Rim at Cape Royal.*

(PHOTOGRAPH FROM UNION PACIFIC RAILROAD COMPANY.)

Again, it has been possible to make one real check upon the actual lengths of time indicated by this newly available timepiece. Doubtless in the future, other checks will also be made. Certain rocks in the Green River basin of Wyoming and Colorado are seasonally banded, with coarse and fine silt or mud arranged in thin alternating layers in regular rhythmic sequence. Similar banded clays were formed in lakes in the Connecticut Valley in front of the retreating ice of the vast glacier which covered New England during the Great Ice Age. In all those cases, one layer represents the accumulation of mud during the winter, the next the summer deposit, and so on, year after year. The length of time required for the formation of the entire deposit may therefore be ascertained by counting the number of layers, two for each year. The method is analogous to that of determining the age of a tree by counting its rings of growth.

In the Green River formation, the annual deposits have been carefully measured and counted. The eleven- to twelve-year sun-spot cycle is indicated by an eleven- to twelve-year rhythm in the variations in thickness of the annual deposit, and another 21,000-year cycle apparent in the rocks is believed to represent the 21,000-year rhythm accompanying the precession of the equinox. The total time recorded by the annual deposits of this formation is about 7,000,000 years. This agrees perfectly with the interval accorded to this particular subdivision of geologic time

on the basis of lead-uranium ratios, although it is very much longer than any geologist would have expected twenty years ago. This confirmation of the radio-active timepiece from an unexpected source is especially encouraging, and there now seems to be no reason for doubting the correctness of the age determinations based upon it.

Unfortunately, the radio-active clock has no second-hand. Its smallest unit of measurement is many millions of years. It is of no value to the student of recent geologic time, that portion of earth history during which man has aspired to the position of monarch of all that he surveys. Some other measure of the passage of time must therefore be used. A timing device comparable to the split-second stop-watch of the athletic field is necessary when attention is directed toward the detailed record of the more recent episodes in earth development.

Geologically, the history of man is intimately associated with the advance and retreat of the glaciers which covered vast areas of North America and Europe during the Great Ice Age. The extent of the several ice sheets is known from the autographs left by the ice on rock ledges, the boulders transported by the glaciers and strewn upon the landscape where the ice melted, and the irregular piles of crushed and pulverized débris from the glacial mill. The interval of time which has elapsed since the ice left these relics of its activity is determined in many ways, some of which are quite precise and others more general.

The most accurately measured portion of geologic time is the most recent—the time during which the last of the ice sheets were dwindling to disappearance. As the ice melted, lakes and ponds were frequently formed at or near its margin. Into these the melt water carried the finer sand and clay which had been imprisoned in the ice. This material was in large part deposited on the lake floors to form such clay banks as those which underlie the Hackensack Meadows near New York City or appear at many places in the Connecticut Valley. Quite commonly the clay and sand were deposited in regular thin layers, often only a fraction of an inch in thickness, which show a remarkable alternation between coarse and fine texture. Such laminations are known as varves and are a result of seasonal variations in the weather during the time that they were being formed.

The coarse sandy varves represent the summer season when the ice was melting rapidly and the open water of the lakes was being agitated by the winds. During the winters the lakes froze over and the glaciers melted slowly if at all. At that time the finest of the silt and clay, which tended to remain in suspension in the lake water during the summer, gradually settled to the bottom through the quiet water of the ice-bound lake and formed the fine dark varves. If therefore one counts the number of pairs of these layers in any deposit of varved clay, he may discover the number of years required for its accumulation.

This method has been checked with beautiful ac-

curacy by the study of the mud now forming on the floor of Lake Geneva in Switzerland. That lake is fed by streams issuing from melting glaciers in adjacent Alpine valleys, and its eastern end in particular is being rapidly filled with sediment from the silt-laden Rhone River. Bottom samples dredged from the floor of the lake show the alternating summer and winter layers formed during the last fifty years. Cold years are represented by thin layers, warm years by thick ones. Mother Earth's record of the weather checks precisely the records of the weather bureau made at the Meteorological Station maintained at Geneva by the Swiss government!

Inasmuch as weather strictly speaking is not a local matter but varies similarly from year to year over an entire state or group of states, it is possible to correlate the annual varves from place to place. Each ten or twenty years has its own characteristic sequence of warmer and cooler, wetter and drier years, its own peculiar arrangement of thin and thick, extraordinary and average varves. For instance it may be determined that the uppermost of four hundred and fifty-four varves in a clay pit near Hartford were deposited during the same decade that witnessed the accumulation of the lowermost of three hundred and ninety varves in what is now a brickyard near Springfield, 25 miles farther north, up the Connecticut Valley. In this way it is possible to fit together the fragments of Mother Earth's diary from place to place and decipher whole chapters of her biography.

Antevs computes that it required 4,400 years for the last ice sheet to melt so that its southern margin retreated from the vicinity of Hartford, Connecticut to St. Johnsbury, near the Vermont-Quebec boundary line. Assembling and correlating the data available from the varved clays at many localities in the northeastern states and eastern Canada, we find that an interval of approximately 25,000 years elapsed while the ice was melting from its maximum spread until it had completely disappeared from that area.

It has not been possible to extend the late glacial and post-glacial chronology in North America until it merges into the known dates in the ancient history of man. In Scandinavia this has been done. There the last of the glacial varves can be dated with reference to the man-made calendar, and it can be said with a fair degree of accuracy that the ice-front stood north of the island of Bornholm in the Baltic Sea about the year 11,600 B.C. and near Ragunda about the year 6,600 B.C.

A somewhat less accurate, but still very satisfactory method of determining the length of time since the ice-front retreated from certain localities is based upon the rate at which such topographic features as Niagara Falls have been changing. The Gorge of Niagara has been formed by the recession of the Falls from their initial position near Lewiston, New York, to their present site. This has all been accomplished since the waning ice first permitted the waters of

Lake Erie to escape northward and plunge over the Niagara escarpment into the basin of Lake Ontario. The rate at which the Falls have receded during the last century is directly measured from the comparison of surveys made in 1842 and 1875 with those of more recent years. Allowance must be made for changes in the volume of Niagara River indicated by the different widths of various portions of the Gorge, but it is fairly certain that the date at which the Falls began to operate is not far from 25,000 years ago. At that time the ice margin stood across the Ontario Basin and much of the St. Lawrence Valley was still buried beneath the great glacier.

All these bits of information when properly correlated, lead to the conclusion that the last great climax of refrigeration occurred about 30,000 to 40,000 years ago. At that time, all of New England was covered by the ice sheet, the southern border of which stood along the line extending the full length of Long Island as shown in Figure 7. This ice finally melted away from northeastern North America about 10,000 or 15,000 years ago.

This was not the only glacial episode during the Great Ice Age. Successive deposits of glacial débris, with soils or interglacial sands and clay between them, have been formed at many places. In the Don Valley, near Toronto, there is one exposure which reveals glacial deposits beneath lake beds which are in turn overlain by another glacial deposit. Leaves and other plant fragments in the lake beds indicate that during

FIGURE 7. *During the latest episode, all of New England was covered by a thick mantle of ice. On this map, the terminal moraine and the first recessional moraines, which mark the limits of the ice sheet at its maximum spread and shortly after it had begun to retreat, are shown in solid black; the general direction of ice movement is represented by the heavy lines which lead to the terminal moraine.*

(AFTER GOLDTHWAIT, IN ANTEVS, "RECESSION OF LAST ICE SHEET IN NEW ENGLAND.")

that interglacial interval the climate was somewhat milder than it is today at that locality. Altogether, five episodes of ice extension, with four comparatively warm interglacial intervals, are recorded as the major events of the Great Ice Age in North America.

There is no precise method of measuring the length of these interglacial intervals or of determining the time which has elapsed since the first four episodes of climatic refrigeration were at their climax. It is possible to date them, however, in a general way. The glacial deposits of central Illinois and southern Ohio, for example, are obviously very much older than those of northern Illinois and central Ohio. The boulders distributed by the earlier ice are commonly quite deeply weathered, whereas those of the last stage are ordinarily so fresh that they retain the polished surface and scratches which were developed while they were being carried in the slowly moving ice. Water trickling through the pile of débris left by the older glaciers has thoroughly oxidized the pulverized rock materials or leached the soluble lime which they originally contained. Surface water, running off the hillsides in rills and rivers, has greatly modified the appearance of the landscape and has carved valleys, broad and deep, where formerly the ice had stood. Comparisons of the amount of such erosion and weathering reveal the fact that the so-called Iowan glacial drift must be three or four times as old as the Wisconsin, the last of the glacial deposits. Similarly, the Illinoian drift is at least twice as old

as the Iowan. Thus we arrive at the conclusion that the oldest of the glacial stages, the Nebraskan, must have occurred one and a half to two million years ago.

The calendar of the Great Ice Age is by no means so precise as might be desired, but it nevertheless gives a fairly accurate basis for dating the more recent events in the physical history of the earth. To it and to the earlier chronology indicated by the solid rocks of the earth's crust, the history of animals and plants must be related.

The nature of the living creatures which were in existence at the time that each successive layer or series of sedimentary rocks was deposited is frequently indicated by the fossil content of those rocks. Fossils are the relics of ancient life preserved in the rocks of the earth's crust. They may consist of mineralized shells of such animals as clams, snails or crayfish, or of the petrified bones of animals possessing a bony skeleton. Occasionally the soft tissues of an animal's body are preserved as carbonized films upon the bedding plane of a rock. In order to be fossilized, an animal's body must be buried rather promptly after the creature's death in the sand or mud of a sea or lake floor, or must soon be covered by the silt swept along a river bed. Thus entombed, the organic material of shell or bone is commonly changed by infiltrating water which replaces the perishable tissue with mineral matter. Ordinarily the new substance replaces the old so faithfully that even the minutest structures are preserved.

The condition of petrified skeletons of the larger animals depends only in part upon the success of this replacement process. Instead it is largely determined by what happened to the animal's body after death and before complete entombment in the midst of accumulating sediments. The bones of land animals especially are very likely to be badly mutilated and broadly scattered by exposure to the weathering agencies or by the currents of the stream along the bed of which they are being transported to some place of lodgment. At certain localities hundreds of bones of many different individuals have been indiscriminately mixed together by the swirling eddies of a river or dumped unceremoniously amongst the mud and silt of a delta. On the other hand, many remarkable instances are known of complete skeletons fossilized with each bone nearly or quite in its original position. Some are a result of the burial of animals which were caught in sand storms; others of individuals trapped in quicksand or boggy ground; still others are apparently carcasses which reached a lodgment basin before the soft tissues had time to decay.

Occasionally even such delicate structures as the wings of a butterfly have been preserved as fossils. One such instance was the result of a volcanic eruption in Colorado during an episode of mountain building in that state. Great quantities of finely pulverized volcanic ash settled down upon the surface of a lake and buried many insects which were either asphyxiated by the gases from the volcano or were killed by

the heavy dust descending relentlessly upon them. Falling with the volcanic débris into the lake, the insects were promptly buried and some of them have since gained the distinction of a prominent position in a museum exhibit.

Sometimes the flesh and hide of an animal's body are partially preserved as a carbonized film upon the bedding plane of a rock. In this way, structures not suggested by the bony skeleton are recorded in Mother Earth's diary. One of the most interesting illustrations pertains to the curious group of fish-like reptiles known as ichthyosaurs. These quadrupeds became marvellously well adapted to life in the water and closely imitated a fish in their general appearance, with fin-shaped flippers instead of legs, a fish-like tail fin, and even a median fin directed upward from the middle of the back. The tail fin was inferred from the fact that the vertebral column was bent sharply downward a few inches from its rear extremity. When only two or three petrified skeletons of the ichthyosaur were known, it was debatable whether or not this sudden bend in the tail vertebræ was a result of accidental displacement or a normal feature. When, however, more specimens were discovered, each with the bend at about the same place, it became apparent that it must be a natural arrangement of the bones. The logical explanation was that the animal had a tail fin, one fluke of which was strengthened by a bony support. Later a few specimens were found in which the carbonized flesh had

been preserved. These verified completely the inference which had been based solely upon the fossil bones. Furthermore, these specimens revealed the presence of the additional fin on the ichthyosaur's back, a structure which, like the camel's hump, is not suggested in any way by the skeleton alone.

Not infrequently the fossil is simply a mold or imprint formed of consolidated sand or mud which was indented, when soft and moist, by the body of the creature. Tracks, trails and footprints formed on tidal flats exposed at low tide, along the shores of lakes, or left in the soft mud of a river bank are often of great significance. These "footprints on the sands of time" are identical in their mode of formation to the similar markings which may be observed today on many a sandy beach or tidal flat. Many creatures, large and small, leave a record of their activities on the moist sand or mud between high and low water marks along the shores of existing lakes and seas. As a rule, this record is completely destroyed by the waves of the next storm or as the next high tide advances. Occasionally, however, the incoming water advances quietly and spreads a film of sand, silt or mud upon the somewhat compacted surface with its ripple marks, rill lines, trails, worm tracks and footprints. Where sediment is thus deposited intermittently to build higher the sea or lake floor, conditions are frequently afforded for the preservation of such records in the consolidating rocks of the earth's outer shell. Incidentally, one of the oldest air-breathing

quadrupedal vertebrates is known solely from such a record. The animal had strolled across a tidal flat exposed at low tide and apparently was caught in a thunder-shower at the time, for the little circular depressions made by spattering raindrops are superimposed upon the footprints of this first known venturesome amphibian.

The fossils of plants generally consist of the carbonized remains of their more resistant tissues such as the stems, stalks, leaves or fruiting bodies. Occasionally the record is the cast of a tree trunk buried in the mud of a delta or in the sand of a river bar. Or again the plant tissues may be truly petrified: replaced by mineral matter deposited from infiltrating water some time after the plant fragments were buried. This last method of preserving the record of ancient botanical conditions is frequently the more valuable as it usually involves the faithful preservation of the delicate cellular structures.

In each case the relative age of the fossils is deduced from the physical relations of the rocks in which they are entombed. The sequence of the rocks themselves must be ascertained before one can be certain concerning the sequence of life. The geologist knows that primitive types of animals and plants lived upon the earth before more complex and highly organized creatures had developed, not because the former are the more primitive, but because their remains are found exclusively in rocks which on account of their physical relationships are known to be

older than those in which the so-called higher forms of life are recorded.

By putting together all these scattered bits of information, it is possible to construct a geological time-table. The recorded history of the earth is divided into five great eras, in the last of which we are now living. Each of these eras is given a name which suggests the character of the life known or inferred to have been in existence during the interval. The Archeozoic is the era of archaic or primitive life. The Proterozoic is the era of "earlier or former" life, the name being based upon a comparison between its life and that of the next following era. The name of the third of the five eras, Paleozoic, is suggestive of the fact that the life recorded in its rocks is "old or ancient." The Mesozoic is the era of "medieval or middle" life and the Cenozoic is the era of recent or modern life.

Although the names used by the geologist are thus characteristically based upon the biologic development of the earth's inhabitants, the eras are actually demarked by important physical events in the history of the earth's surface features. Thus, the Archeozoic rocks may be defined as all the rocks formed before the making of a great mountain range formerly existing in Canada where now is the "height of land" between the St. Lawrence River and the Hudson Bay drainage system. Those mountains have long since been worn down and cast into the sea. The lead-uranium content of the rocks which long ago were elevated into that mountain system indicates that

ERAS	PERIODS		MOUNTAIN-MAKING EPISODES	LIFE	YEARS B.C
CENOZOIC	QUATERNARY	RECENT	("THE GREAT ICE AGE")	AGE OF MAN	25,000
		PLEISTOCENE			2,000,000
	TERTIARY	PLIOCENE	ALPS	AGE OF MAMMALS	
		MIOCENE			35,000,000
		OLIGOCENE			
		EOCENE			60,000,000
MESOZOIC	CRETACEOUS		ROCKY MOUNTAINS	AGE OF REPTILES	
	JURASSIC		SIERRA NEVADA		
	TRIASSIC				205,000,000
PALEOZOIC	CARBONIFEROUS	PERMIAN	APPALACHIANS		300,000,000
		PENNSYLVANIAN		AGE OF FISHES	
		MISSISSIPPIAN			
	DEVONIAN				
	SILURIAN		SCOTTISH HIGHLANDS		450,000,000
	ORDOVICIAN			AGE OF INVERTEBRATES	
	CAMBRIAN				600,000,000
PROTEROZOIC			YOUNGER LAURENTIANS		
ARCHEOZOIC			OLDER LAURENTIANS		1,260,000,000

FIGURE 8. *The geologist's time table.*

they were formed approximately one billion, two hundred and sixty million years ago.

The Proterozoic Era extends from the milestone provided by that oldest known mountain-making episode to a time when volcanoes were in great activity in what is now northern Michigan and southwestern Ontario. Somewhere near the middle of that era there was a second wide-spread crumpling of the earth's crust accompanied by the injection of vast quantities of molten rock material from the deeper interior into the outer shell of the earth. This involved among other things the birth of the second generation of ancient mountains in the Laurentian area. These earlier chapters of Mother Earth's diary are extremely difficult to decipher; the pages are torn and tattered; many important sections of the record are entirely missing. But with the beginning of the Paleozoic Era, it is possible to discover the chronologic sequence of events in far greater detail. Changes in the geography of land and sea, minor disturbances of the earth's crust which gave rise to local mountain systems, serve as the milestones to mark the opening and close of the several periods into which this and the subsequent eras are divided. The more important of these mountain-making episodes are indicated in their appropriate relations on the accompanying diagram. Near the end of the Paleozoic Era the Appalachian Mountain system first came into existence. Similarly the close of the Mesozoic Era is marked by extensive upheavals in the western part of North

America, which gave rise to the Rocky Mountain system.

As one would expect, the history of animals and plants is closely related to these changes in the geography and topography of the land. The age of invertebrates begins at an unknown date in the Archeozoic Era, continues through the Proterozoic Era and may be said to terminate at the close of the second period in the Paleozoic. At that time the fishes, a more complexly organized type of animal, began to invade the seas and promptly became dominant therein. The age of fishes covers four of the Paleozoic periods, extending from approximately four hundred and fifty million years to approximately three hundred million years ago. It was followed by the age of reptiles which covers the last period of the Paleozoic and the entire Mesozoic Era, extending to a time which was only about sixty million years ago. The birth of the Rocky Mountains is not only the milestone that marks the close of Mesozoic and the beginning of Cenozoic time, but it also celebrates the downfall of the reptiles and the advent of mammals. With the beginning of the Pleistocene Period—the Great Ice Age—which opened about two million years ago, man became an important factor among the inhabitants of the earth and it may therefore be asserted that the age of mankind began at that time.

The record of humankind and of closely related prehuman ancestors is very inadequate and incomplete. These creatures were all inhabitants of the land,

many of them dwelling in forested uplands. Their remains therefore were very rarely fossilized. Only an extremely fortunate accident of natural burial of a dead body in a river delta or its preservation in a sheltered cave would yield a record which might be preserved to the present day. Primitive man, active and intelligent as he must have been, was not nearly so likely to be caught in a swamp or quicksand as were the huge mammoths or giant sloths of his day. It is therefore not surprising that so few fossilized bones of humankind have been discovered.

Fortunately many of the most significant bones in the human skeleton are the very ones which are most resistant to decay and destruction. Bones of the jaw and brain case are of the greatest value because they reveal the critical features which distinguish the human strain from the anthropoid apes. Many of the records of prehistoric man consist only of a fragment of the jaw or skull. Although these seem like trivially small portions of the entire human body, they are nevertheless the very portions which indicate the progress of the peculiar development for which man is noteworthy.

Our knowledge of prehistoric man is based only in part upon the fossilized bones. Much more abundant is the record of the things which he has made, such as arrow points, bone scrapers, flint hammers, etc. All such manufactured articles are technically known as artifacts and the progress of human culture is remarkably revealed by the workmanship which the

artifacts of the various ages display. Crudely chipped stone implements are not always distinguishable from flint fragments which have been broken by running water as they have been washed along a stream bed, or crushed by a landslide where flint-bearing gravels have been exposed on a steep slope. Doubtless there will always be debatable objects which may or may not have been the result of manipulation by a brain-controlled hand. But well-designed implements are obvious and these reveal a story of remarkable interest and importance.

Occasionally the fossilized bones of human beings or their ancestors are found in the same beds of gravel or layers of sand with flint implements or other artifacts. In the earlier records this association is always an accidental one, but later as mankind reached higher levels of psychologic and esthetic development the practice of burying weapons, food jars and ornaments with the body of the dead became a common one. It is thus possible to relate certain types of artifacts to the creatures who made them, though this cannot always be accomplished. A considerable part of the record consists of implements alone, unrelated to any fossil bones.

Chapter 2

The Stream of Life

"Rise after rise, bow the phantoms behind me," WALT WHITMAN

In order to speak intelligently about the objects of their study, it is necessary for scientists to divide those objects into groups of varying dimensions according to some rational plan. Students of animal and plant life have therefore developed a precise and detailed classification of living creatures. Familiar to all is the reference of various objects to three "kingdoms": mineral, animal and plant. Most of us can easily recall our childhood days when we played games involving the definition of objects with respect to these three categories, a definition which was often difficult for us to make with any degree of certainty. Obviously, the assemblage of creatures which belong in the animal kingdom is an extremely large and varied one; it must therefore be divided and subdivided into ever smaller and more homogeneous groups. Zoologists consequently recognize at least nine "branches" of the animal kingdom. Each branch

includes one or more "classes." The classes in turn are subdivided into "orders," the orders into "families," the families into "genera" and the genera into "species."

Thus, man is scientifically known as Homo sapiens, the supposedly sapient or wise species of genus Homo. This genus belongs in the family Hominidæ, which is one of several families in the suborder Anthropoidea in the order Primates of the division of Placental Mammals in the subclass Viviparous Mammals, one of the two major divisions of the class Mammalia in the Vertebrate branch of the animal kingdom.

The classification of animals, like any other classification of objects in nature, is based upon certain fundamental similarities or differences which appear in their body structure. In general, the degree of structural resemblance is inferred to indicate the degree of relationship, although much care must be taken to differentiate superficial resemblance of fundamentally different structures from those similarities in form and structure which are truly indicative of close relationship. In the selection of the characters upon which a classification shall be based, the skeletal features, body form, arrangement of muscles, organs and other parts of the adult individual are strongly emphasized. But to the facts of comparative anatomy is added the study of embryonic, prenatal and juvenile development. It is readily apparent in the life history of many an individual that certain

fundamental characteristics which appear before birth, or shortly after birth, disappear later or become quite inconspicuous; and these earlier characteristics may be most important indicators of the real relationship existing between various individuals or groups.

Every classification of animals or plants is necessarily an artificial one. Life is to be likened to a flowing river, in which the adjacent drops merge one with the other, rather than to a series of separated pools, each of which is isolated from its neighbors by water-tight compartments. The animal life of the earth cannot be distributed among the pigeonholes of the old-fashioned roll-top desk. Every attempt to establish hard and fast distinctions between groups of individuals, large or small, has failed. Sooner or later, a creature is discovered in some remote or inaccessible spot on the earth's surface, or preserved among the fossils of antiquity, which refuses to fit into the proposed scheme of things. Just as many of us found it difficult in the childhood game to decide in which of the three kingdoms a particular object belonged, so the trained scientist often has difficulty in putting certain creatures into one or the other of the great kingdoms. For example, there are living plant-animals, individual creatures which combine the essential characteristics of plants on the one hand with those of animals on the other. Still more difficult is the task of assigning animals to classes, families and genera. Existing differences of opinion among biologic classifiers simply reflect the fact of underlying

unity and continuity throughout the entire animal realm. Classifications, in the very nature of things, are artificial and arbitrary.

There is no such thing in nature as a species of animal or plant; the only natural units are individuals. A species is simply a group of individuals which scientists believe are so closely related to each other that for purposes of description and study they may be considered as a unit. In the progress of time scientists change from one opinion concerning the boundaries of such units to another. A species is therefore a matter of definition, a group of similar individuals which has recently been designated as such by trained observers. Many species interbreed with each other; some species are sufficiently different from all other living forms so that they cannot breed with individuals outside the descriptive bounds established for them.

Recognizing therefore the continuity of the stream of life as contrasted with the requirement of the human mind for schemes of classification, we may survey man's place in nature. Obviously man belongs in the branch of vertebrates, the group of animals possessing a spinal column of cartilage or bone and displaying an enlargement of the front portion of the central nervous system to form a brain. Likewise he belongs to the class of mammals, the warm-blooded vertebrates whose bodies are naked or more or less completely covered with hair, the females possessing mammary glands for nourishment of the young.

There are two subclasses of mammals: one is represented by a very small group of egg-laying creatures such as the spiney ant-eaters and the duck-billed mole. These live in comparatively isolated and inaccessible parts of the earth's surface and are unknown to the majority of people. Their young are hatched from eggs and then for a time are suckled by the mother.

The other mammals are viviparous—that is, their young are produced alive from within the body, rather than from eggs which hatch after being deposited. In this great division of viviparous mammals there again are two subdivisions: marsupials and placentals. In one, the young are born in a very immature stage of development, and are promptly placed by the mother in a pouch upon the abdomen with their mouths upon the mammary glands. Here they are carried for a considerable time until they are ready to take care of themselves. The opossum and the kangaroo are the best known of the pouched or marsupial mammals. Their infancy is in striking contrast to that of the new-born colt or calf who scampers around the barnyard an hour after he is born.

This subdivision of the viviparous mammals shows only slight advance over the egg-laying mammals, as the egg is merely retained within the body of the female until all of its food supply is exhausted by the growing young. Since there is no mechanism for continued nourishment of the embryo within the

body of the parent, the offspring must then be born or die. Hence the young are born in a very immature stage of development.

The other and larger subdivision of viviparous mammals is in fairly sharp contrast, as its young are nourished for weeks or months within the womb of the female parent and consequently are in a comparatively advanced stage of development at birth. These mammals are known as "placentals," for they possess at appropriate times an organ, the placenta, in which the blood-stream of the mother is brought into close proximity to the blood-stream of the embryonic young. There is no mingling or mixing of the blood, but nourishment is transmitted through the thin delicate membranes which alone separate the two blood-streams. This makes possible the extension of the prenatal existence far beyond the period limited by the store of food in the eggs of other vertebrates. Presumably it is one of the most important of the factors which have given to the placental mammals their present position of great numerical and physical importance in the entire animal kingdom.

Most of the familiar animals of the field, forest and farmyard are placental mammals. Their diversity in appearance and mode of life is such as to make necessary further subdivision of the group if we are to talk about them intelligently. It is, however, a difficult task to separate them into "orders," and there is at present no unanimity of opinion among those who have attacked this problem. Certain outstanding

distinctions are nevertheless apparent. Horses, cattle, sheep, goats, camels and deer possess hoofs for the protection of their toes and for efficiency in locomotion. These also are characterized by the presence of grinding teeth adapted to a vegetable diet. They and their allies contribute several orders of "hoofed herbivores." Cats and dogs are in contrast typical of the "clawed carnivores," their toes being provided with efficient means for grasping their prey and tearing through hide or sinew, and their teeth eminently adapted for cutting flesh. Another group is partially or completely aquatic and includes the seals and whales.

Still another group of placental mammals is marked by the presence of nails on the tips of fingers and toes rather than claws or hoofs. These also possess teeth of a generalized nature, rather than ones specialized for either herbivorous or carnivorous habits. Though their food is typically nuts, fruits and eggs, they also eat flesh or grain with comparative facility. This is the order of "Primates" and it is of course to this order that man belongs. The order comprises two suborders: the lemuroids, which includes the strange nocturnal tarsier as well as the lemur; and the anthropoids, in which man is associated with the monkeys and apes.

Having placed man in his proper biologic perspective in relation to other animals, we are now ready to survey the records left along the banks of time as the stream of life swept forward from the

ancient dawn of earth history into the bright noontide of present scientific knowledge.

The oldest known rocks contain no recognizable fossils whatever. Among the limestones formed during the Archeozoic Era there are certain structures which are doubtfully identified as indicative of the presence of lowly forms of animal or plant life, but no definite picture of the nature of that life has been preserved for us. In rocks of the Proterozoic Era there are remains of microscopic algæ and other simple plants with certain markings which may with considerable confidence be interpreted as trails and burrows of worm-like animals. The oldest known fossils are petrified filaments of extremely small plants apparently identical with the blue-green slime which grows in stagnant pools or the algal structures so abundant in the hot springs of Yellowstone Park and elsewhere. These tiny tubes and filaments are visible only under a high-powered microscope in thin translucent sections cut through the pebbles of an early Proterozoic conglomerate from Minnesota. The algæ which left this record must have lived while the rock from which these pebbles were eroded was being deposited as an extremely fine siliceous ooze upon the floor of an ancient lake or sea, possibly in Archeozoic but certainly at least as long ago as early Proterozoic time. Before the end of the Proterozoic Era extensive deposits of limestone were formed in large part from the precipitations consequent upon the presence of lime-secreting algæ—tiny, colonial plants which then

as now lived in great profusion in certain favorable environments.

With the beginning of the Paleozoic Era, there is found for the first time a considerable abundance of recognizable fossil remains. In rocks of Cambrian age are preserved the records of representatives of every one of the great branches of invertebrate animals. These Cambrian invertebrates for the most part are very primitive in their body forms and structures; nevertheless most of the fossils may be referred definitely to such branches of the animal kingdom as the molluscs, echinoderms, corals and arthropods. No vertebrate fossil nor anything suggesting a vertebrate animal has been found in Cambrian strata. The most highly organized of the common Cambrian animals were the trilobites, an extinct type of arthropod, the branch of invertebrates which includes the modern crayfish, lobster, spiders, ants, butterflies and other insects. Trilobites possessed a well-constructed nervous system with compound eyes, antennæ, and other sense organs. The movements of their jointed legs, efficient jaws and complex body structures were apparently well coördinated by the nerve centers, but there is nothing to suggest a spinal cord or brain.

In the next younger series of rocks, formed during the Ordovician Period, occurs the oldest known record of vertebrates. It consists of the battered and fragmentary remains of an extinct subclass of primitive fishes, known as ostracoderms. Their ancestry is still in doubt. From the nature of the rocks

FIGURE 9. *Trilobites were the most highly organized inhabitants of the early Paleozoic seas. Their compound eyes, antennæ and other sense organs indicate a complex and efficient nerve system.*

in which the fossil fragments are entombed, it appears likely that these animals had evolved from their invertebrate ancestors in the fresh water of rivers, as the known remnants of their bodies are contained in the mud of a river delta.

The only important missing link in the entire chain of life, connecting the one-celled animals at one end with man at the other, is that which must have intervened between the first fishes and their invertebrate progenitors. If one is really interested in discovering the missing link in the evolutionary chain, he should look therefore in early Paleozoic rocks for a record of that unknown ancestral form. From the fishes, through the higher classes of vertebrates, to man, the record is quite clear. There are of course many minor steps in the development of the vertebrates concerning which our knowledge is by no means complete, but the broader relationships of the various generations are now fairly well established. The connection between the fishes and their ancestors is the one important exception to the rule.

The failure to discover that connecting link is presumably to be attributed to the environmental conditions under which it existed. Very few of the early Paleozoic rocks known to geologists were formed above sea level; most of the known Cambrian and Ordovician strata are marine. If at some place the geologist could find fossiliferous formations which had accumulated on the land as river deposits during those early Paleozoic periods, there would be a good

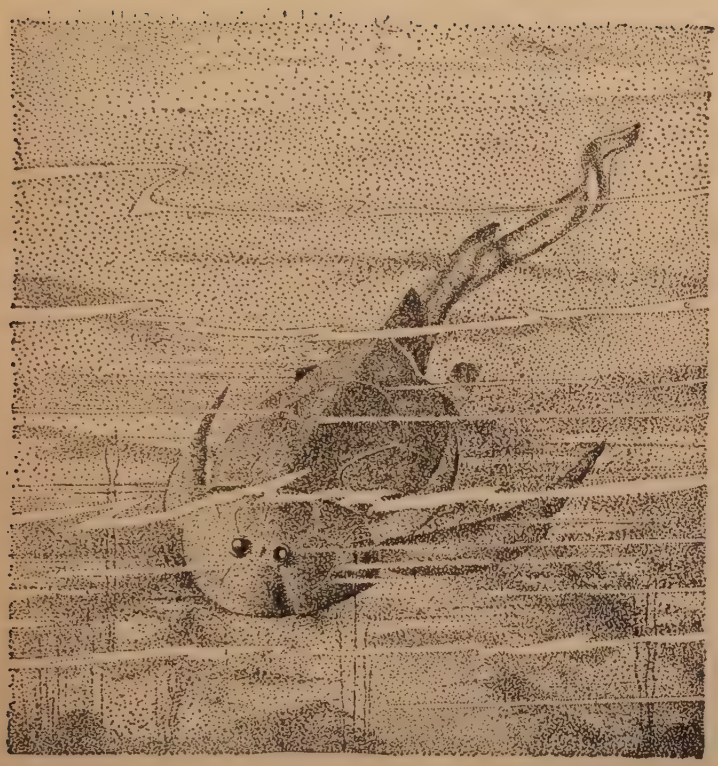

FIGURE 10. *The oldest known vertebrates belonged to an extinct group of primitive fish-like creatures, the ostracoderms. The drawing is based on a restoration displayed in the New York State Museum at Albany.*

chance of discovering a record of the immediate ancestors of the fishes. Perhaps some day such a discovery will be made.

If, as we now believe, the first fishes were inhabitants of rivers, the necessity of maintaining their

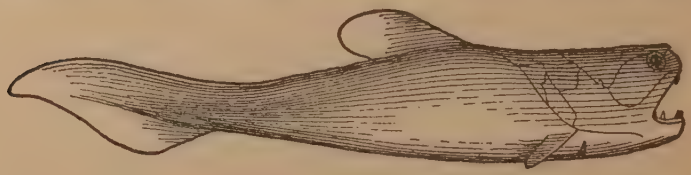

FIGURE 11. *Many of the Devonian fishes were provided with bony armor plate over the front part of their bodies.*

position against the rushing current would be likely to impose upon them the flexible stream-line body which later proved of great advantage when they migrated downstream and entered the sea. This migration seems to have taken place during Silurian time. Certainly by the beginning of the Devonian

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PLATE II: A. *The Green River formation is exposed at the surface of the earth in northwestern Colorado and adjacent parts of Utah and Wyoming. It is a very fine-grained mudstone with remarkably regular laminations, believed to be due to seasonal fluctuations in the weather during its accumulation.* (PHOTOGRAPH BY D. E. WINCHESTER, U. S. GEOLOGICAL SURVEY.)

B. *The polished surface of a small specimen from the Green River formation displays the seasonal bands, or varves, which enable the geologist to compute the length of time required for the deposition of this unusual sedimentary rock. In this instance the result of the computation—7,000,000 years for the entire formation—checks closely with the time interval recorded by the radio-active timekeepers described on page 14.*
(PHOTOGRAPH BY W. H. BRADLEY, U. S. GEOLOGICAL SURVEY.)

A

B

Period the fishes were well adapted to life in the sea and had already deployed into several different subclasses. Among these are no representatives of the modern group of bony fishes. Most of these Devonian animals had heavy armor plate upon the exterior of their bodies and only cartilaginous skeletons. The true bony fishes with well-developed scales were still wanting from the record. In other words, this early record of fish life is of comparatively primitive rather than of highly developed forms, which is a good reason for concluding that the record indicates a time very near the actual beginnings of the fishes in the waters of land and sea.

One of the subclasses of Devonian fishes was ancestral to the amphibians whose footprints are observed first in early Carboniferous strata. The ascent of vertebrates from the water in which they breathed by means of gills, onto the land where they used lungs for the purification of their body fluids, was one of the most notable forward steps in vertebrate development. It involved the perfecting of an accessory breathing organ possessed in the Devonian Period by a large number of fishes and still retained by the modern "lung fishes" which are in a certain sense "living fossils." "Lung fishes" are at present confined to the waters of tropical lands where there is great fluctuation between the floods of the rainy season and the stagnant pools of the river bed during the dry season. When there is an abundance of water they behave like normal fishes, breathing by means of their

gills, but as the river level begins to fall at the close of the rainy season they burrow into the banks of the stream and remain in mud-walled holes during the long rainless months which characterize such climatic regions. Even though they are now out of the water they do not die, provided the mud around their bodies remains moist, for they possess a mechanism for breathing air which is analogous to the lungs of land animals. They are temporarily an exception to the rule that fishes breathe throughout life by means of gills.

The accessory breathing organ of the "lung fishes" is nothing but the air bladder commonly found in other fishes, but used by them merely to give their bodies the necessary buoyancy in the water. When the goldfish comes to the surface of the water in its bowl and gulps a few mouthfuls of air, it is simply renewing its buoyancy; the habit has nothing to do with respiration. But in the "lung fishes" the air bladder is surrounded by a network of tiny blood vessels which permit a purification of the body fluids quite similar to that which takes place in human lungs. This enables the fish to live through the adverse conditions of the dry season, when the dwindled remnants of the former rushing streams are stagnant and unfit to serve as habitations for fastidious creatures. To be sure, the blood must still pass through the gills as it makes the circuit of the body, and therefore the delicate membranes in those organs must be kept constantly moist else they harden and clog the blood-

stream. For that reason if the mud plastered around the body becomes completely dried the animal dies.

Although at the present time there are only two or three species of "lung fishes," in the Devonian assemblage more than one-third of all the hundreds of known species of fish belonged in this category. Some of them at that time took the suggestion thus provided concerning the next step in the progressive improvement of vertebrates. Once the accessory breathing apparatus was sufficiently perfected so that it became a satisfactory lung, they were ready to leave the overcrowded waters and start to explore the comparatively vacant territory of the dry land.

Curiously enough, the modification of the air bladder into a respiratory organ had a very unexpected effect upon vertebrate evolution. Although lungs thus replaced gills so far as their function was concerned, they did not actually replace the gill structure in the body of the animal. In consequence the newly achieved lung was by no means as efficient in purifying the blood-stream as were the ancestral gills. As long as the gills were the organs of respiration a two-chambered heart could pump the blood in one direct circuit through them to all parts of the body and back again for purification. Head, body and tail regions alike received pure blood from the gills. But the lungs were not in the same relation to the blood system as were the gills. Instead they were so placed that when the blood left the two-chambered heart a part of it went directly to the head while another

part went to the lungs for purification. Thence the pure blood travelled on to the middle and rear portions of the body. Returning to the heart it was now at least partially impure, and it was this less desirable fluid which was pumped to the head without opportunity for purification. Presumably this explains the fact that for many geologic periods the majority of air-breathing vertebrates displayed huge bodies and small heads. Without adequate nourishment, brains had no opportunity for real improvement. The development of intelligence as the crowning product of evolutionary progress had to wait until the handicap consequent upon the unfortunate relation of lung to blood system had been overcome. This was finally accomplished by the development of the four-chambered heart which characterizes the mammals. One pair of chambers pumps impure blood to the lungs, whence it returns purified to the other pair of chambers which distribute it impartially to all parts of the body. The double circuit makes possible the proper nourishment of head and brain, but it was not perfected until the Dark Ages of earth history, the Mesozoic Era, had been well-nigh spent.

Modification of fins into legs suitable for locomotion on the land paralleled the development of the air-breathing apparatus, but with consequences which were immediately satisfactory. The new organ replaced the old both structurally and functionally. In fact the well-known architecture of the limbs of all higher vertebrates was determined by the arrange-

FIGURE 12. *The way in which fins were modified into legs is shown by these drawings of the shoulder girdle and front limb of a Devonian lobe-finned fish, at the top, of a late Paleozoic amphibian, at the right, and of a hypothetical intermediate stage, at the left. H, humerus; R, radius; U, ulna.*

(AFTER GREGORY, IN "THE UPRIGHT POSTURE OF MAN.")

ment of the bony plates in the fins of Devonian fishes. Figure 12 presents this arrangement, as displayed in one of many fossil remains of the fringe-finned fishes of that time, in comparison with the leg bones of one of the oldest known quadrupeds, an amphibian of Carboniferous time.

The human limb possesses one long bone between shoulder and elbow, hip and knee, and two bones between elbow and wrist, knee and ankle. Every air-breathing vertebrate has exactly that arrangement of bones or some modification of it. The plan is fundamental and the various locomotor appendages are simply variations of the theme, resulting from changes in the shape and dimensions, rather than the arrangement of the three bones. The particular plates in the fin of the Devonian fish, which were the forerunners of the individual bones in the human arm and leg are readily identifiable. The design was initiated among the "lung fishes" and it has been basic in all subsequent plans. Possibly, a leg in which two bones extended from hip to knee and only one was present between knee and ankle could have been designed just as effectively, but such was not the case.

The first air-breathing offspring of the fishes were amphibians. Hatched from eggs the individuals for a time breathed by means of gills, but as each passed from youth toward adult stages it abandoned the water and depended exclusively upon its lungs for respiration. The frog is the best-known of modern amphibians, but the salamander or mud-puppy is

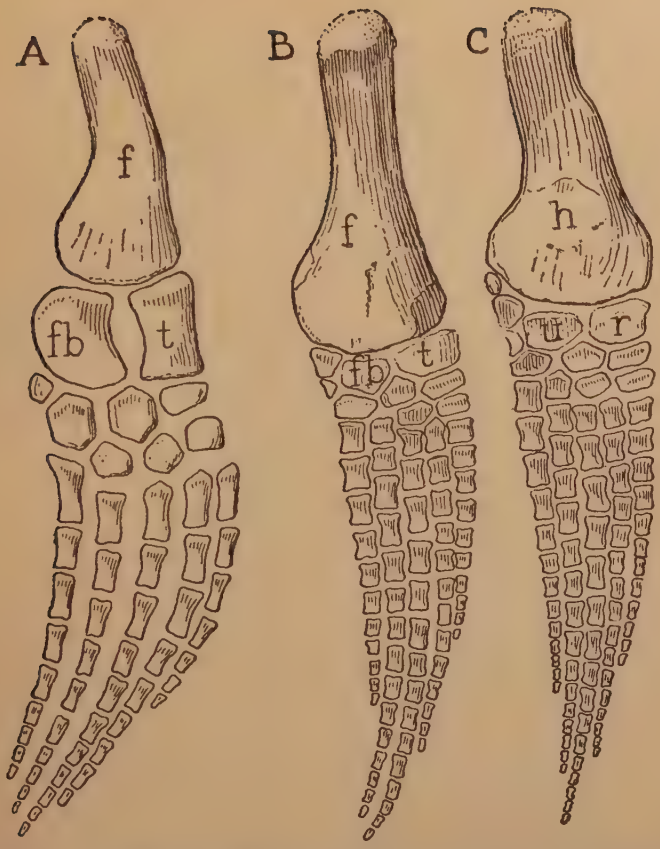

FIGURE 13. *Plesiosaur paddles are legs which have been greatly modified in order to provide that marine reptile with an efficient means of propulsion through the water. The basic design of the vertebrate leg is nevertheless apparent. A is the right hind paddle of an early plesiosaur, and B and C are right rear and front paddles of a later, more advanced plesiosaur. f is the femur, the bone between hip and knee; fb and t are the fibula and tibia, the two bones between knee and ankle; h is the humerus, the bone between shoulder and elbow; u and r are the ulna and radius, the two bones between elbow and wrist.*

(AFTER WILLISTON, IN "WATER REPTILES OF THE PAST AND PRESENT.")

more typical of the earlier representatives of this class. Most of the Paleozoic amphibians were heavy-bodied, clumsy, short-legged, broad-necked creatures, such as those shown in Figure 14, which pictures also the type of vegetation abundant at that time. The landscape displayed no grasses, fruit trees or flowering shrubs, only evergreens, ferns and spore-bearing plants such as club-mosses and "horse-tails." Its monotonous greens and browns must have been a striking contrast to the colorful vistas of the present time.

Amphibian footprints and petrified bones are fairly abundant in rocks of the Carboniferous Period, but the amphibians were masters of the land for only a brief interval of time. Very promptly the change to reptiles was accomplished. Here the record is so complete that there are available several skeletons of Carboniferous quadrupeds which cannot be referred with certainty either to the class of amphibians or that of reptiles although they must belong to one or the other. They are in very truth transitional forms. The chief difference between amphibian and reptile is found in the fact that amphibian eggs, like those of the modern frog, must be deposited and hatched in the water. For at least a few moments the young amphibian has the habits of a fish and breathes by means of gills. The tadpole stage may be very short, but in each amphibian the metamorphosis from tadpole to frog stage may be observed after birth. In contrast, reptile eggs are deposited on the land. In the

FIGURE 14. *Eryops, shown here in his native haunts, was a late Paleozoic amphibian, ancestrally allied to the reptiles.*
(AFTER WILLISTON, IN "WATER REPTILES OF THE PAST AND PRESENT.")

prenatal life of the young reptile the gill-breathing stage is passed within the egg. When the reptile is hatched the lungs are ready to function. This frees the reptiles from the necessity of returning to the water to deposit their eggs and represents the next necessary adjustment in the process of developing a distinctly land-living vertebrate. This transition was

FIGURE 15. *Some of the huge herbivorous dinosaurs measured eighty or ninety feet in length from the front of their ridiculously small heads to the tip of their tails.*
(AFTER CHARLES R. KNIGHT, BY PERMISSION OF THE AMERICAN MUSEUM OF NATURAL HISTORY.)

accomplished fairly early in the Carboniferous Period, and long before the Appalachian Mountains were brought into existence at the close of the Paleozoic Era the reptiles had begun to deploy into various orders.

Among these there appeared early in the Mesozoic Era the well-known order of dinosaurs, destined to dominate the life of the land throughout the

greater part of the "Age of Reptiles." Promptly they established a precedent for terrestrial quadrupeds by separating into two divisions, one of which was carnivorous, with teeth and claws designed for tearing flesh, and the other herbivorous, with grinding teeth and blunt, stubby toes. It was among the latter that the largest land animals known upon the earth were developed. Impressive and terrifying must have been those huge creatures with elephantine legs and tremendous bodies as they stalked across the landscape. Some individual specimens extant measure ninety feet in length along the spinal column from the tip of the ridiculously small head to the tip of the slender tail. Yet they were as harmless as a cow, for they subsisted entirely upon a vegetative diet. Presumably they sought "safety in size" from their carnivorous relatives, and by their huge bulk compensated for their lack of agility and speed.

The space within the skull available for the brain of one of these huge beasts is scarcely large enough to accommodate a man's closed fist, although the entire body must have weighed two or three tons. Actually, the nerve ganglia in the pelvic region were more voluminous than the brain. "More brains in the hips than in the head" is a true characterization.

Another family of herbivorous dinosaurs matched the offensive armament of their carnivorous cousins by developing defensive armor in the form of a great bony shield extending from the base of the skull backward toward the shoulders. This was ac-

companied by three bony horns which must have served in good stead when the bulky herbivore was attacked by the more agile carnivores. It was the eggs of the frilled herbivorous dinosaurs which were found in Mongolia a few years ago by Roy Chapman Andrews and his colleagues from the American Museum of Natural History. Although these eggs

Figure 16. *Other herbivorous dinosaurs protected themselves with bony horns and massive shields extending backward from the base of the skull. This one, known as Triceratops, was somewhat larger than an elephant.*

were about a hundred million years old, had not been kept in cold storage, and were very much the worse for wear, their market price was high—$5,000 per egg. But, then, they are rather large eggs with a diameter three or four times that of a hen's egg. The fact that they are actually the eggs of dinosaurs is known, not simply from their occurrence in the same Cretaceous strata as those which carry the dinosaur fossils, but from another observation. Some of them

have been cut into thin sections which reveal the petrified bones of unborn dinosaurs! In the same way, if a hen's egg should be removed from the incubator on the twentieth day of incubation and placed in the right environment for fossilization, the bones of the

FIGURE 17. *That dinosaurs were hatched from eggs is definitely known from the presence of fossil remains of unborn young within the petrified eggs found in Mesozoic rocks in Mongolia.* (AFTER E. M. FULDA, BY PERMISSION OF THE AMERICAN MUSEUM OF NATURAL HISTORY.)

chick, not quite grown to the point of hatching, would be preserved. Using this information, the artist has prepared a sketch, Figure 17, which represents an "Easter Morn in the Cretaceous Period" with the infant dinosaurs breaking free from the confining

egg-shell. This is an excellent example of the way in which intimate and unexpected details of ancient life history are occasionally recorded.

One strain of smaller, light-limbed, agile carnivorous dinosaurs led the first successful expedition

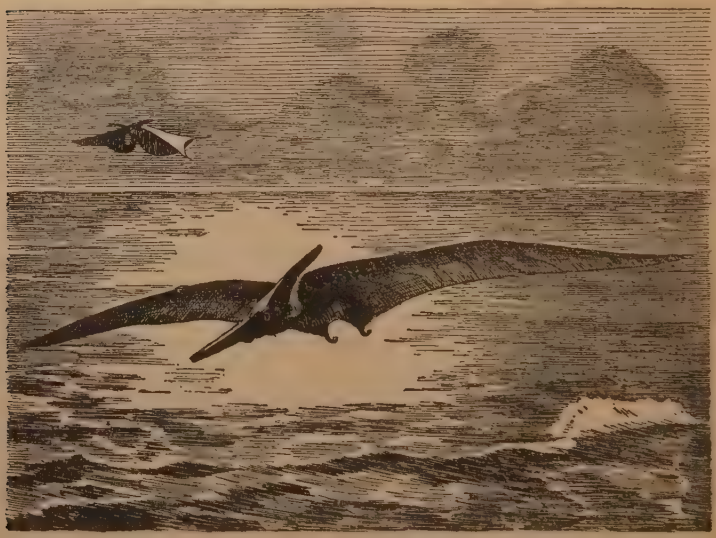

FIGURE 18. *Flying reptiles with a wing-spread of twenty-five feet were the lords of the air during the Cretaceous period.* (AFTER DRAWING MADE UNDER THE DIRECTION OF PROFESSOR LANGLEY, BY PERMISSION OF THE AMERICAN MUSEUM OF NATURAL HISTORY.)

sent by the vertebrates into the air. Early in the Mesozoic Era there lived a group of flying dragons which might well have served as the basis for the legends of classical mythology or the fables popular during the Middle Ages when knighthood was in flower. The front limbs were greatly elongated by a

remarkable extension of the bones of arm and hand. From the framework thus provided a bat-like membrane was stretched to the body and rear legs. Mother Earth had designed the first monoplane! Some of these flying reptiles or pterosaurs had a wing spread of

Figure 19. *Archeopteryx, the oldest known bird, is a link between reptiles and birds. It possessed teeth, claws on its wing supports, and a vertebrated tail.*

twenty or more feet and were remarkably efficient flyers, able to ascend to great heights and then descend swiftly to impale a fish or other animal upon their long, slender, sword-like jaws.

The pterosaurs were not the ancestors of birds.

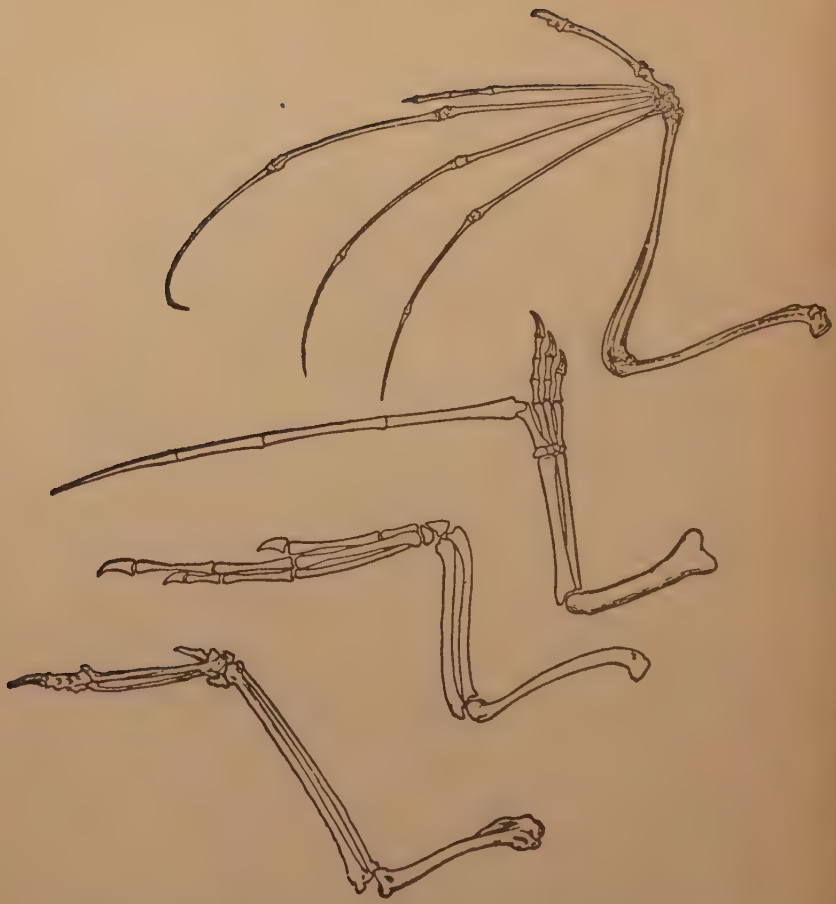

FIGURE 20. *Three different methods of fashioning a wing support are represented by the wing of the bat, at the top of the page, the wing of a flying reptile, next below, and the wings of Archeopteryx and a modern bird at the bottom.*
(AFTER LUCAS, IN "ANIMALS OF THE PAST.")

Instead, it was still another group of active carnivorous dinosaurs which gave rise to that important class of vertebrates. Fossils of the transitional forms are known from rocks of the Jurassic Period. They represent a small, primitive bird with reptile-like skeleton, a vertebrated tail and toothed jaws, but with the imprint of unmistakable feathers accompanying the petrified bones, which had they not been so accompanied would have been identified as belonging to an order of reptiles closely allied to the dinosaurs.

When they had become masters of the air as well as lords of the land, the reptiles longed for other worlds to conquer and sent several expeditionary forces into the sea, promptly gaining supremacy there. The aquatic reptiles, returning thus to the environment of their remote piscene ancestors, did not in any sense go back to the earlier organic structures which had been modified or abandoned by their progenitors. Although it would have been distinctly to their advantage to revert to the use of gills for respiration, none of them show the slightest tendency toward restoration of that organ. Dependent as they were upon lungs, they were forced frequently to come to the surface of the water to breathe. Similarly, it would have been advantageous to turn back the evolutionary cycle and regain the fins which had long before been altered into legs. But again, without exception the aquatic reptiles were characterized by the presence of flippers or paddles, analogous to those of seals and whales, and in each case a modification of

the legs which had been perfected expressly for locomotion on the land. In no case, throughout the entire record of life development, is there a violation of the rule that an organ once lost or greatly modified is never regained. The evolutionary processes seem not to be reversible.

Nevertheless, the new adjustment to the old environment proved very satisfactory, and the aquatic reptiles promptly became the scourges of the sea, feeding upon the fishes and invertebrates which dwelt therein. Their legs were so completely modified that they were extremely efficient organs of locomotion in the water, and among one group, the ichthyosaurs, the entire body form closely imitated that of the fishes. Adaptation to the aquatic environment was so complete in that group and also in the plesiosaurs that those reptiles must have been extremely clumsy and therefore at a great disadvantage whenever they tried to scramble around on land. And there was one reason why for a time at least an occasional excursion on the shore was necessary: reptile eggs could not be deposited in the water. That was a privilege which had been lost during the transition from amphibians to reptiles. If the aquatic reptiles could have returned to the egg-laying habits of their ancestors, the fishes and the amphibians, there would have been no necessity for any of them ever to set foot, or flipper, upon dry ground. But the handicap was there, until at last the ichthyosaurs overcame it. One fossil specimen of an adult ichthyosaur contains within its body cavity the

petrified bones of several infant ichthyosaurs with such relationships as to make it apparent that these are unborn young. The ichthyosaur eggs had been retained within the body instead of deposited for incubation; ichthyosaurs are the first vertebrates known to be viviparous. Thus the last tie that bound them to the land of their fathers had been severed, and they were now able to spend their entire lives uninterrupted in the sea. Thus, also, this group of marine reptiles foreshadowed the habits of marsupials concerning the birth of young; indeed, it is highly probable that they, like the mammals, were warm-blooded.

In spite of these remarkable advances, the Mesozoic Era presents a rather sad picture as seen from the vantage point of the present enlightened civilization. The reptile rulers of the three great spheres of mundane activity, the land, the sea and the sky, were bloodthirsty brutes. Brawn rather than brains, weight rather than wits, was the order of the day. Doubtless this triumph of brute strength is in large part traceable to the failure of the circulatory system to nourish the head with pure blood as effectively as the middle and rear parts of the body. Not until the four-chambered heart of the higher vertebrates had been designed and perfected was it possible for head and brain to exceed body and brawn in importance.

Had one looked at the earth in Cretaceous time he doubtless would have said, "How can any good ever come from this welter of bloodthirstiness and cruelty? Surely the world has gone mad in its lust for

huge dimensions, sharp talons and powerful claws. This is the triumph of selfishness in which success is measured in terms of ability to arm oneself for attack or for defense!" The artist who years ago sketched Figure 21 was very inaccurate in his representation of

Figure 21. *This drawing, the original of which was made many years ago when the science of paleontology was still in its infancy, is quite inaccurate in its details of reptilian anatomy, but it suggests admirably the "spirit of the times" during the Cretaceous Period, when cold-blooded brutes were the rulers of sea and land and sky.*

the details of later Mesozoic anatomy, but he seems to have caught the "spirit of the times."

Yet scurrying out from under the feet of the ponderous reptiles there were a few small mammals, the forerunners of a better day that was to come. In the closing stages of the Carboniferous Period one

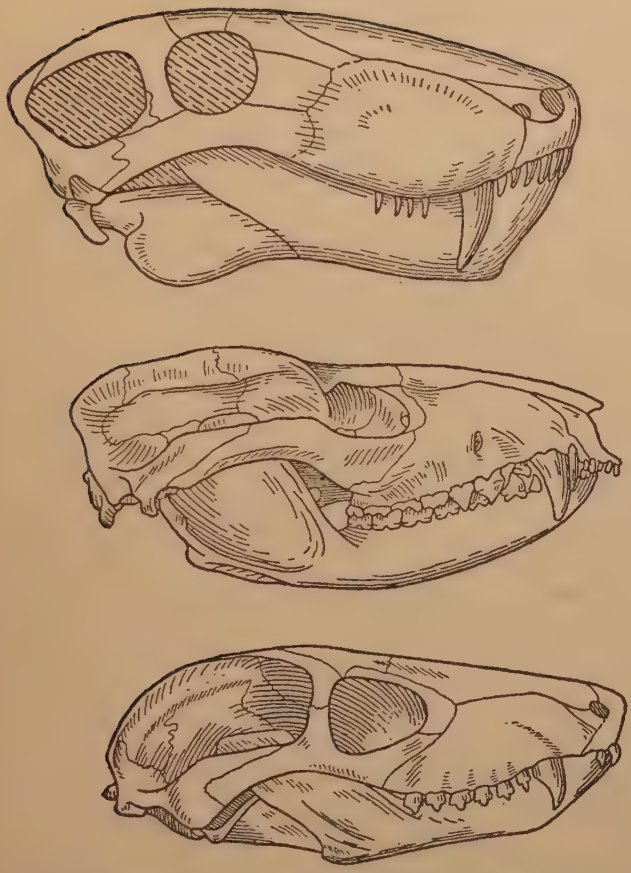

FIGURE 22. *Mammal-like reptiles foreshadowed true mammals in latest Paleozoic and early Mesozoic time. The skull at the top of the page is that of an early representative of the "mammalian strain" of reptiles, the one in the middle is a later member of that "strain", and at the bottom of the page is the skull of an opossum, typical of the more primitive mammals.*

(AFTER GREGORY, IN "OUR FACE FROM FISH TO MAN.")

strain of reptiles had already begun to show certain modifications which foreshadowed mammalian structures. Mammal-like reptiles are recorded in latest Paleozoic and earliest Mesozoic rocks in the southwestern states and in Africa, but it was probably in the latter locality that the transition from them to primitive mammals was consummated. The differentiation between the two strains of reptiles is notable.

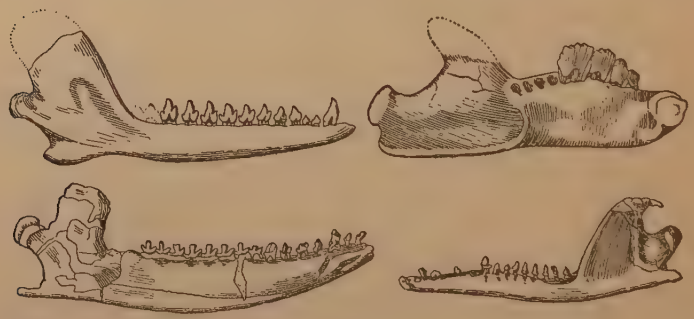

FIGURE 23. *Fossil jaws and teeth of egg-laying and marsupial mammals are fairly common in the rocks deposited during the latter half of the Mesozoic Era.*
(AFTER O. C. MARSH.)

On the one hand there is the large group which includes the horde of Mesozoic masters as well as all modern reptiles, and from which the birds arose; on the other, there is the small group which gave birth to the mammals. Their differentiation is evident in the earliest records of reptilian life, and it is indeed even possible that the cleavage had taken place before the transition from amphibians to reptiles had been completed.

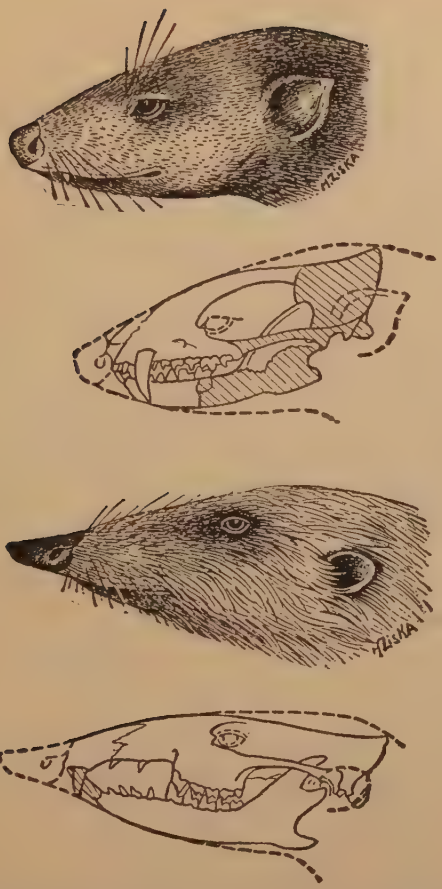

FIGURE 24. *The fossils of placental mammals, recently discovered in Cretaceous formations in Mongolia, indicate small shrew-like creatures with characteristics which suggest that they were ancestral to the Tertiary placentals. Two of the best preserved skulls are shown here in outline, with a restoration of each to show how it may have appeared when its possessor was alive...*
(FROM GREGORY, "OUR FACE FROM FISH TO MAN.")

In any event, the fossil jaws and other bones of small inconspicuous mammals, either egg-laying or marsupial, are found in the rocks of each period of the Mesozoic Era. In later Cretaceous time these are fairly abundant and indicate a definite increase in number and improvement in ability in spite of, or possibly in part because of, the overburden of reptile dominance with which the mammals had to contend.

Figure 25. *The pen-tailed tree shrew is a native of Borneo where its geographical isolation has preserved it from competition with more powerful mammals. Its characteristics are so archaic that it well deserves the designation, a "living fossil."*
(after a wash drawing by Helen Ziska in Gregory, "Our Face from Fish to Man.")

Quite recently, there was discovered in Mongolia the first known record of Mesozoic placental mammals. These were tiny creatures resembling rather closely the modern tree-shrew of Borneo, another of our "living fossils." These tiny creatures from Asia are typical of the Mesozoic ancestors of the placental mammals which were to dominate the Cenozoic Era and rule the "Age of Mammals."

With the close of the Mesozoic Era, commemo-

rated by the birth of the Rocky Mountains, the reptilian rulers of land and sea and sky were blotted out of existence. Of Mesozoic reptiles only the crocodiles, lizards, snakes and turtles have survived that revolutionary episode in earth history. Promptly thereafter the placental offspring of the recently discovered Mongolian mammals took possession of the vacant spheres of activity. Among these were the first of the primates, the order to which man belongs.

The stream of life had thus moved far from its source. Despite the eddies and backwash, the main current had swept resistlessly forward. A new type of creature was about to arise in which intelligence and cooperative spirit were to feature prominently among the standards which determined fitness to survive. With this in mind, the mammals surely deserve consideration in a new chapter.

Chapter 3

The Family Tree of the Higher Vertebrates

"It isn't where a man came from, it's what he brought with him that counts." C. A. CARMAN

The first four periods of the Cenozoic Era constitute the "Age of Mammals" and are conveniently denoted as comprising Tertiary time. Official usage of the United States Geological Survey refers to this geologic interval as the Tertiary Period and subdivides it into four epochs, but it is increasingly the practice among geologists to recognize the great importance of this portion of earth history by elevating the four subdivisions to the rank of periods.

The name Tertiary is an inheritance from the early geologic notion that the oldest rocks at the earth's surface constituted the original crust, congealed during the cooling of the globe from an initially liquid state. Such rocks would be truly "Primary," and it was long believed that granites such as those which form the basement beneath the horizontally bedded strata in the Grand Canyon deserved

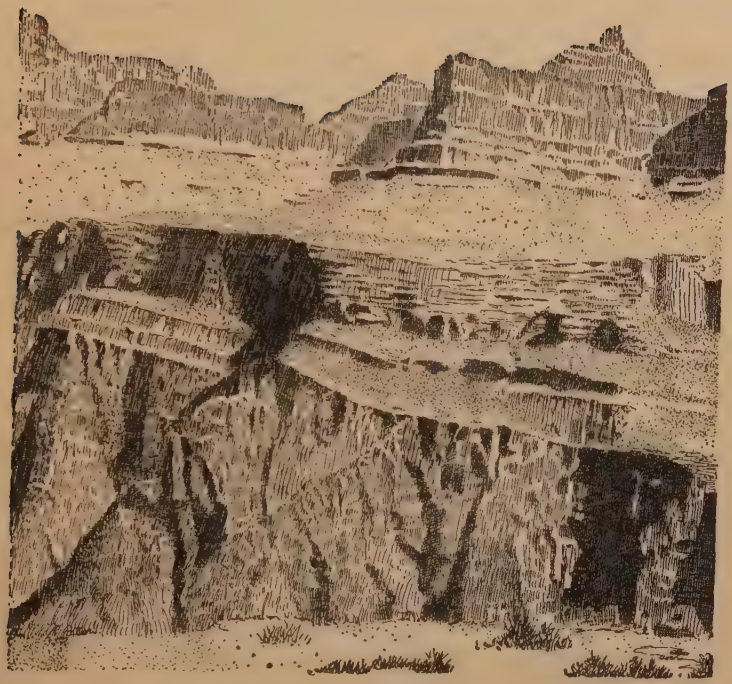

FIGURE 26. *The lowest slopes of the inner gorge in the Grand Canyon are composed of Archeozoic granite which was once believed to be a "Primary" rock, but is now known to be intrusive in still older Archeozoic rocks of sedimentary origin. Resting on the eroded surface of the granite is a series of gently inclined Proterozoic sedimentary rocks which are in turn overlain unconformably by the flat Paleozoic strata which are piled layer upon layer to the very brink of the canyon.*

this appellation. Obviously, the rounded crystals of quartz, which constitute the sand grains in a sandstone, had come from such granites during their disintegration, and therefore sandstone and similar "derived rocks" were designated as "Secondary." Then, it was observed that pebbles or other fragments derived from the erosion of the Secondary rocks were included in still other sedimentary formations. These must therefore be "Tertiary," the third system of rock materials in the outer shell of the earth. Finally, there is strewn over the land at most places a veneer of broken or weathered fragments, not consolidated into rock, but constituting a fourth system, the "Quaternary," because among these fragments were recognizable bits of Tertiary conglomerates.

In this way, the idea crystallized that earth history could be divided into four periods on this very simple basis. Unfortunately, we now know that even the oldest granites are in no sense "primary," but were intruded into still older rocks of the type which would have been designated as "secondary" had their real nature been understood. Nothing approximating an "original crust" of the earth has been discovered anywhere, and it is extremely unlikely that any truly "primary" rocks are exposed at any place. These ancient terms thus have lost their significance, and two of them have well-nigh disappeared from current usage. The terms Tertiary and Quaternary are still retained in geological nomenclature, however, al-

though their original meaning has long since been abandoned.

The first period of Tertiary time, or the first epoch of the Tertiary Period, is known as "Eocene," which being interpreted means the "dawn of the recent." It is followed in sequence by the "Oligocene," "somewhat recent"; the "Miocene," "slightly recent"; the "Pliocene," "more recent"; and the "Pleistocene," "most recent." Post-Pleistocene time is "Recent." The Tertiary interval, as the name is now used, beginning with the Eocene, about sixty million years ago, closes with the Pliocene, about two million years ago. Pleistocene and Recent time together constitute the Quaternary interval.

The geography of North America during Tertiary time was quite different from that of today, although the major outlines of the continent were much the same. As a result of crustal disturbances which marked the close of the Mesozoic Era, there were in the far western part of the continent many ranges of high and rugged mountains, separated from each other by intervening, low depressions, not unlike the present "Great Valley" of California. Into these basins between the mountains, the streams which were vigorously eroding the higher lands brought great quantities of sand and silt and gravel during the successive Tertiary stages. This material was spread at the foot of the mountains and upon the basin floors, building the lowlands higher and higher. In places, the Pacific Ocean temporarily lapped at the

western foot of the Sierra Nevada or other ranges, and there the land was built out into the water, enlarging the area of dry land. Elsewhere, the intermontane depressions were at times occupied by lakes into which a part of the débris was washed. But for the most part, the lowlands were semi-arid deserts or broad expanses of verdant plain, upon which the mountain streams were depositing a large share of the materials which they carried downward from the mountain gorges.

In these non-marine deposits have been found hundreds of thousands of fossil bones of the animals which dwelt upon the land during Tertiary time, for conditions were eminently suited for the preservation of the remains of such creatures. Caught in the quicksand of a river bed, mired in swamp or marsh, drowned in the attempt to ford a swift stream, their bodies were frequently buried promptly after death, before their skeletons had disintegrated. Or wandering across a desert lowland, a veritable Tertiary "Death Valley," many a hapless creature was caught in a sudden sand-storm, suffocated and buried where it died. These are about the only opportunities that a land animal has for becoming a fossil. Such opportunities were many times repeated, and therefore these rocks of the western states contain many petrified bones.

But to gain admission to a museum of natural history a creature of bygone days must not simply be fossilized; it must also contrive to have its remains

discovered by a fossil hunter. It happens that many of the present exposures of Tertiary lake-bed or river deposits are in regions which today are deficient in rainfall. There the occasional torrential downpour, typical of semi-arid climates, has carved the bare hillsides into an intricate network of gulches and ar-

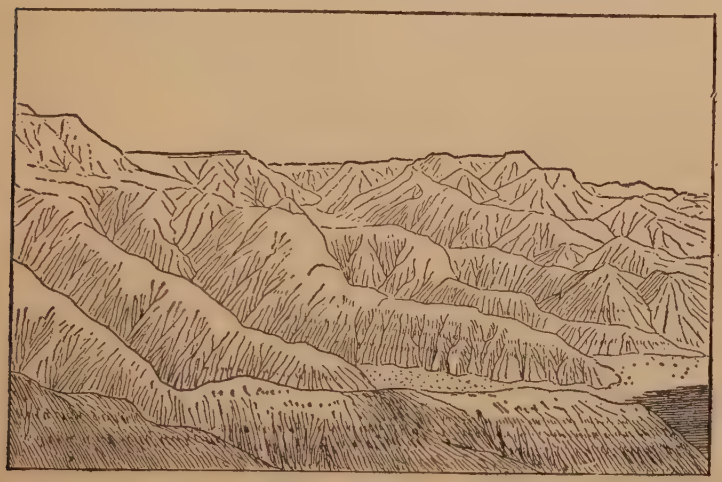

Figure 27. *The Badlands of the western states, in spite of their well-deserved name, have proved to be a paradise for the fossil hunter. Thousands of skeletons of Tertiary mammals have been secured from the crumbling rocks of these much-dissected hillsides.*

royas, justifying the name "badlands," which is applied to such localities. In spite of the name these constitute the fossil-collector's paradise, for innumerable stream channels and absence of vegetation give abundant access to many parts of each layer of rock. Even in a few years, the rapid erosion of the hillsides makes notable changes and uncovers additional por-

tions of the strata. Hillsides carefully robbed of every exposed fossil one year may yield additional booty five or ten years later. From such localities many of our most significant and interesting relics of the Age of Mammals have been secured.

The record is a most impressive story of change and development among the higher vertebrates. For the mammals, Eocene time is scarcely the "dawn of the recent." No existing genus and scarcely any living family of mammals is recorded in Eocene rocks. Most of the earliest Tertiary mammals bear only a remote resemblance to their modern offspring.

Carnivores were represented by a group of heavy-limbed, short-necked, low-skulled creatures known as creodonts. They lacked the efficient sharp-edged teeth which like a pair of shears enabled the later sabre-tooth tigers and the modern cats to sever

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PLATE III: A. *Fossil ichthyosaurs from the Mesozoic rocks represent Nature's most complete adaptation of a land animal to life in the water. The fact that this marine reptile possessed a fish-like tail was inferred from the sharp bend in its vertebral column, but the presence of the fin on the middle of its back was known only after specimens such as this were found, in which the flesh was partially preserved as a film of carbon upon the bedding plane of the enclosing rock*

B. *When the fossil hunter is on the trail of the ponderous dinosaurs which roamed the land during the Age of Reptiles, his task of collecting petrified bones sometimes assumes the proportions of large-scale quarry operations. In this photograph, reproduced by permission of the American Museum of Natural History, the backbone of a huge herbivorous dinosaur is partially revealed in the foreground, and the bones of the creature's leg are uncovered in the middle distance at the right. Upon skeletons such as this, is based the sketch shown in Figure 15.*

A

B

a tendon or cut swiftly through hide and sinew, and their claws could not be extended or retracted at will.

The earliest Eocene herbivorous mammals looked more like a dog or a large gopher than like a horse or deer, yet they possessed teeth designed not for tearing

Figure 28. "*Little Eohippus was no larger than a fox,*
And on four toes he scampered over Tertiary rocks;
'But,' said little Eohippus, 'I am going to be a horse,
And on my middle finger-nails, I'll run my earthly course.'"

flesh but for cropping and grinding vegetation, and their toes terminated not in claws but in tiny hoofs, five to each foot. These clumsy five-toed condylarths would have had little chance to survive had they been forced to compete with the modern cats, but they were on a par with their contemporaries, the creo-

FIGURE 29. *The spectral tarsier, of the East Indies, is the least man-like of the existing primates.*

donts, and apparently "made good" in the rivalry which must have existed between these two types of mammals. The sequence of fossils in the successive Tertiary strata shows that each improvement toward litheness and agility, better teeth and stronger claws among the cat tribe, was matched by an increased ability on the part of the herbivores to make a quick start and maintain high speed as they sought to escape from the stealthy onslaught of their foes.

The oldest known member of the horse family is from middle Eocene rocks and has been named Eohippus, the "Dawn Horse." It was small of stature, about a foot and a half in height, and had four toes on its front feet, three toes on its hind feet, all terminated with hoofs. A comparison with its modern equine descendant gives a most convincing impression of the great changes which placental mammals have undergone since Eocene time.

Such changes as these suggest the probability of equally radical alterations in the ancestors of mankind, but before reviewing the record of the Tertiary primates it is desirable to survey the existing members of this particular order of mammals. The most lowly and least man-like of living primates is the spectral tarsier, an inhabitant of the East Indies. It is a nocturnal creature with huge eyes, well designed for seeing in the dark. Its curious toes terminate in little suction cups which enable it to cling to the branches as it scampers through the tree-tops. Close to the tarsier in structural development are the lemurs of

Madagascar and neighboring portions of Africa. They, too, possess a sharp fox-like muzzle and a relatively small brain. Tarsiers and lemurs comprise the suborder lemuroidea which is today quite sharply

FIGURE 30. *The lemur is today confined to Madagascar and adjacent regions, but in early Tertiary time there were lemur-like animals in North America, Europe and Asia, as well as in Africa.* (AFTER A DRAWING BY HELEN ZISKA, IN GREGORY, "OUR FACE FROM FISH TO MAN.")

differentiated from the other primate suborder, the anthropoidea.

Anthropoids have a more or less man-like face and a relatively larger brain. They are clearly demarked into two subdivisions. One, the platyrrhine or "broad nostril" group, is native only to South and Central America and includes the marmosets as well

as all the various kinds of monkey which live in that region. Most familiar of these is the capuchin, the favorite of the organ grinder, who, dressed in red jacket and cap, begs coins from every passerby as his master turns the crank of the mechanical music-maker.

The other subdivision of anthropoids is the catarrhine or "narrow nostril" group, native only to Europe, Asia and Africa, prior to the recent expansion of mankind into all continents. It includes the "Old World monkeys," such as the baboon, as well as the apes and man. Among the anthropoid apes are four distinct genera: the gibbon, the orang-utan, the gorilla and the chimpanzee. Of these, the gorilla is structurally most similar to man, with a brain which in its details of form and shape is closer than any other brute brain to that of a human being. In general, the structure of the anthropoid apes places them much nearer to mankind than to the monkeys.

At the same time, the differences between man and the apes are noteworthy, important and extremely significant. They justify the isolation of man as the sole member of the family Hominidæ, whereas the chimpanzee, orang-utan and gorilla are grouped together in the family Simiidæ.

With such comparisons in mind, it is not surprising to find that the Eocene primates bore only slight resemblance to modern apes and man. In general, the primate fossils of the lower Eocene show very close relationship to their insectivorous ancestors of

Cretaceous time as represented by the placental mammals from the Mongolian rocks of that age. They were small, long-snouted, agile quadrupeds, fairly well adapted to life in the trees and feeding upon fruits, nuts, eggs and presumably insects, like their immediate progenitors.

Primate fossils have been found in the Eocene rocks of every continent except Australia. One of the best known genera is Notharctus, represented by many fragmentary skeletons and skulls, and by at least one nearly complete skeleton from North America. In appearance this creature had considerable resemblance to a large rat so far as its size, build and structure are concerned. Its skull was low and long, with a distinctly fox-like muzzle except that it terminated in a square blunt end where a series of sharp incisor teeth were placed. The skeleton is very light, with slender bones and with a long, vertebrated tail. The characteristics of the feet are especially important, because the arrangement of the great toe is identical with that observable among all the modern tree-dwelling primates. Members of this order that climb swiftly, easily and energetically among the tree-tops have a long slender great toe like a thumb, twisted slightly so that the ball of the toe is directed toward the other four toes rather than downward as in most animals who spend their lives on the ground. Notharctus therefore was an arboreal animal; his native haunts were the tree-tops.

The teeth of Notharctus are quite generalized and are more numerous than in man. The incisors are projected obliquely forward and there is no suggestion of a chin. In many mammalian strains, or evolutionary lines, there is progressive reduction in the number of teeth with approach toward modern time. This seeems to be a mark of progress and is noteworthy in connection with the human family tree, although man ordinarily possesses thirty-two teeth, several more than is found in many other mammals. It is however not unusual for a human being to fail to cut all four of the third molar or "wisdom" teeth. As a matter of fact the wisdom teeth have nothing to do with intellect, and instead of being a disgrace the failure to produce them may fairly be interpreted as a mark of superior progress.

In the evolution of the skull and jaw from the Notharctus type to the existing monkeys, great apes and man, there have been three notable changes. First, the face has shifted into a position more nearly parallel to the vertebral column on which the skull is set. Second, there has come a gradual development of the chin and relative restriction of the distance between incisors and third molar. This has involved a change in the direction of the incisors from obliquely forward to directly vertical. Third, there has been a noteworthy enlargement of the upper part of the skull, giving more room for the brain. In Figure 31 these factors are displayed as they appeared in Notharctus and in the present stage of develop-

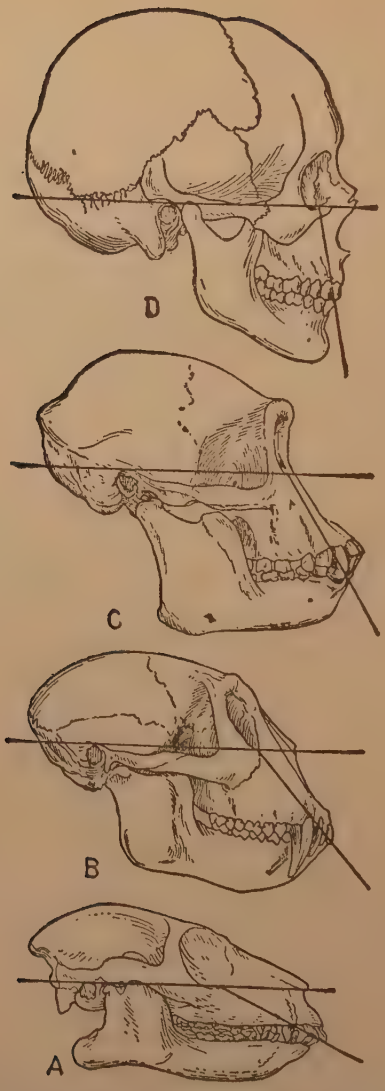

FIGURE 31. *The major trends in the evolution of the human head are suggested by these four primate skulls: A, Notharctus, B, Old World monkey; C, chimpanzee; D, man.*
(FROM GREGORY, "OUR FACE FROM FISH TO MAN.")

ment of the Old World monkey, the chimpanzee and human beings.

The precise position of Notharctus with respect to the suborders, lemuroid and anthropoid, is still a matter of debate, so generalized are the characters of teeth, skull and limbs. Some students of the problem would classify Notharctus as a member of the lemuroidea, whereas others consider it to be a primitive anthropoid. Differences of opinion frequently arise when we are dealing with archaic and transitional forms such as this, and as a rule they are good testimony to the fact that the doubtfully placed individual is an ancestral form. In all probability, Notharctus represents very accurately the type of animal from which most if not all of the existing primates have descended, each individual strain specializing along its own pathway which took it farther and farther away from the common progenitor.

One of these lines of descent from Notharctus led to the platyrrhine monkeys of South and Central America. In early Tertiary time, North and South America were connected by a land bridge which probably followed the great arc of the West Indies from Mexico eastward around the Caribbean Sea to northeastern Venezuela. At that time there was no Isthmus of Panama, and the Caribbean was a Pacific Gulf rather than a great embayment from the Atlantic Ocean as it is today. Southward over this land bridge an expeditionary force of North American land mammals made its way in the Eocene Period. Among

these were the offspring of Notharctus who were eventually to become the New World monkeys. Before the end of the Eocene, the land bridge foundered, and throughout most of Tertiary time South America was isolated from all other continents. The Isthmus of Panama was elevated to join the two Americas comparatively late in the Tertiary interval.

Another group of primates, likewise near relatives of Notharctus, migrated at about the same time from North America to Asia and thence to the connected continents of Europe and Africa, the region in which the next important steps in the evolution of mankind were taken. Following this exodus from North America, the notharctids died out in this their homeland. No fossil primate is known from North American Tertiary rocks younger than the Eocene.

A few years ago two very badly worn molar teeth were found in the Pliocene rocks of Nebraska, and in 1922 Dr. H. F. Osborn of the American Museum of Natural History described these teeth as anthropoid fossil remains, because of their close resemblance to human molars. To the creature which bore them, he gave the name Hesperopithecus, the "western ape." The announcement that an anthropoid fossil had been found in the later Tertiary rocks of North America was naturally received with considerable scepticism by other scientists, on account of the fragmentary nature and poor condition of the specimens and because of the fact that no other anthropoid remains had ever been discovered among

the thousands of Tertiary fossils from this continent. Further search in the same Pliocene formations subsequently revealed additional teeth and fragments of jaw bones. The molars in this newer material were in better condition and gave much more accurate information than the worn specimens first found; it may now be definitely asserted that these teeth and jaws belong to some member of the swine family. The name Hesperopithecus should therefore be abandoned. The mistake was an easy one to make, as both swine and human molars are comparatively generalized, possess many primitive characteristics, and lack the high degree of specialization which enables ready identification of the molars of many other mammals. To the credit of the scientists of the American Museum, it should be stated that they themselves recognized their error and announced it to the world.

The absence of anthropoid descendants of the notharctids from North America forces us to look elsewhere for the next steps in the evolution of the primate strain leading toward man. The Oligocene rocks of northern Africa have yielded a number of important relics. For the most part, these are merely jaws and teeth, yet they are sufficiently well preserved to reveal unmistakably the significant facts concerning the creatures of that time and place. One of the most important of these fossils is known as Parapithecus, which serves as the basis for an extinct family of primitive anthropoids. Parapithecus must have been closely similar in his general appearance and

structural characteristics to the modern tarsier; nevertheless the shape of the jaw and the pattern of the molar teeth are distinctly anthropoid rather than lemuroid. The lower jaw is long and narrow, with little space for the slender tongue. The incisor teeth are directed obliquely forward, yet not so much so as those of Notharctus. There is an extension of the lower part of the jaw, which foreshadows the development of a chin. The sides of the jaw converge rapidly forward from the rear, much more than in any existing ape and in strong contrast to the parallel position of the two sides of the human jaw.

In somewhat higher strata in the same district near Fayum, Egypt, other fossil jaws which show definite advance toward modern anthropoid characteristics have been found. Among these is Propliopithecus, the sides of whose jaw were more nearly parallel, with room in front for a comparatively broad flat tongue. The name Propliopithecus was given to this fossil because it appears to be a forerunner of the genus Pliopithecus which had earlier been described from the Miocene rocks of Europe. Pliopithecus is quite definitely an ancestor of the modern gibbon. But Propliopithecus is an extremely generalized anthropoid, quite capable of serving as the ancestor to all of the modern apes and man as well as to the gibbon.

The Siwalik Hills of India are formed in large part of terrestrial deposits not unlike those of our own western states. In these river-borne sediments and

lake beds a great variety of land animals has been recorded. Among them are many species of anthropoids, the great majority of which are referred to the genus Dryopithecus; most of them lived during Miocene time. The genus Dryopithecus is a broad group of rather diversified nature. Certain of the species show specialization toward the characteristics of the modern gorilla, while others are similarly trending toward the modern chimpanzee type. A critical study of the dentition of Dryopithecus in comparison with that of modern man has led Gregory and Hellman to the conclusion that "from some form of Dryopithecus, possibly related to D. rhenanus, man has inherited his dental formula, the 'bicuspid' pattern of the upper and lower premolars, the 'Dryopithecus pattern' of the molars, many details of the incisors and canines and many important characters of the deciduous dentition." In other words, Dryopithecus from the Miocene rocks of the Siwalik Hills indicates the appearance and structure of our prehuman ancestors in that mid-Tertiary stage.

From the same rocks of the Siwalik region a few scanty fragments of another anthropoid known as Sivapithecus have been collected. The few teeth, jaw fragment and palate are inadequate to indicate its real relationship to other members of the Primate stock; additional specimens must be found before a satisfactory judgment can be given. Pilgrim, the superintendent of the Geological Survey of India, believes that Sivapithecus is even closer than Dryo-

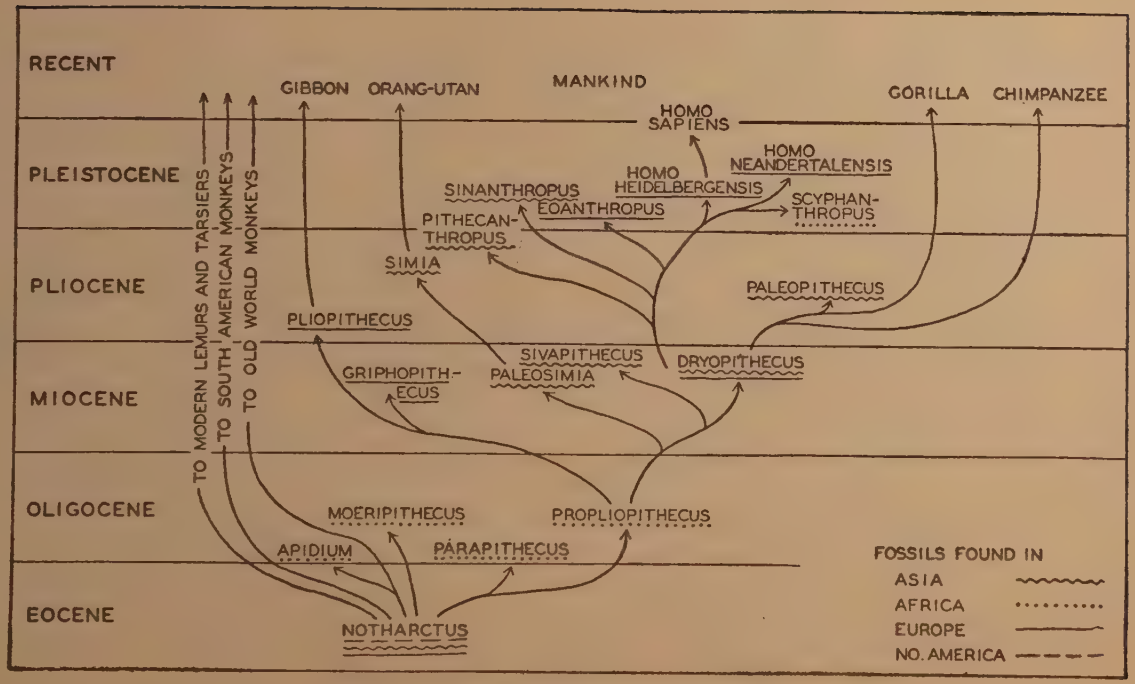

FIGURE 32. *The family tree of the primates.*

pithecus to the strain which leads to man, but his interpretation has not met with the approval of other students of the problem.

Pliocene anthropoids are not uncommon in Africa, Europe and Asia, but with possibly one exception all are distinctly apes, closely allied to existing chimpanzees, gorillas, gibbons or orang-utans, rather than transitional between apes and men. The exception is a most remarkable skull found in a quarry near Taungs in South Africa. That is a region of limestone where deep crevices and fissures lead down from the surface into caves which have been formed by the dissolving action of water trickling through the rocks. At one place the quarrymen worked their way into a small cavern filled with crumbling bones of animals which had fallen or crawled into a fissure which formerly opened to the surface of the ground. These bones represent animals now extinct, but none of them are adequate to serve as the basis for a precise determination of their age. In all probability the whole collection represents a Pliocene assemblage of animals, but it possibly may be early Pleistocene instead.

Among the bones was the skull represented in Figure 33. The face and lower jaw are well-nigh complete; the rear part of the skull is fragmentary, but still sufficiently preserved to give a fairly accurate notion of the whole. Beyond doubt an anthropoid, it has been named Australopithecus, the "southern ape." It is much more man-like than either the

orang-utan or gorilla, with larger brain, smaller face, less protruding jaw, and the face more nearly vertical. There is no clue as to its ancestral development; apparently it represents one of the many experiments that were tried by Old Mother Earth in the attempt

FIGURE 33. *The skull found near Taungs in South Africa is believed to represent an extinct genus of Hominidæ, to which the name Australopithecus is given.*

to improve the intelligence of the primates. It is not a progenitor of any modern creature

With this one exception all known anthropoids of Pliocene age show close affinities to some one of the four living genera of apes. It is therefore apparent that the differentiation of the human branch from

the several ape branches of the anthropoid stock must have taken place at least as early as the Miocene period, approximately twenty-five million years ago.

This conclusion is further indicated by the presence, in upper Miocene and Pliocene rocks of France and England, of flint implements which have undoubtedly been shaped by a designing hand. These so-called eoliths are adequate proof that by the end of the Miocene period an intelligent anthropoid, more man-like in his habits than any existing ape, had come into existence. The shaping of flints implies a marked distinction between the fore and hind limbs and strongly suggests that already an upright attitude and bipedal gait had been attained.

The origin of these human characteristics can only be inferred from the rather scanty evidence which is available. Such evidence, however, all points definitely toward an arboreal or tree-dwelling habitat for man's prehuman ancestors. Almost certainly the upright attitude resulted from the habit of swinging from branch to branch among the trees, suspended by the arms. This habit of "brachiation," as it has recently been labeled, reached its maximum perfection in the modern gibbon. Hanging from a limb by one or both hands, the body is stretched into an erect position. Man was thus literally set upon his feet. Incidentally, it was also good preparation for the habits which today are forced upon many city-dwellers in crowded subway cars. Only after this change in attitude had been effected among the trees

could the habit of walking erect upon the ground develop.

Fortunately,. man's ancestors left the tree-tops and got down upon the ground before the adjustment to brachiation had progressed too far. The gibbon is extremely clumsy on the ground; even the gorilla walks on his hind legs with difficulty and prefers to progress on all fours. This is because the great toe is separated too far from the other toes, with the main axis of the hind legs between the first and second toes, instead of between the second and third toes as it is in man. The hind feet of the gibbon and gorilla are excellently constructed for clinging to a tree-trunk or branch, but they are too highly specialized for that function to serve as the starting point from which a foot like man's could evolve. On the contrary, the human foot has developed from that of the common ancestor of apes and men, with definite adjustment to meet the demands of bipedal locomotion in an erect or semi-erect attitude. The ball of the great toe faces directly downward, and that toe is throughout its entire length in close proximity to the neighboring second toe. The slight differences in relative position and shape of the toe bones are really of the greatest importance and indicate that man's prehuman ancestors had not become greatly specialized for brachiation before they abandoned the tree-tops as an abode. But the custom of an upright position acquired in the trees, freed the fore-limbs from

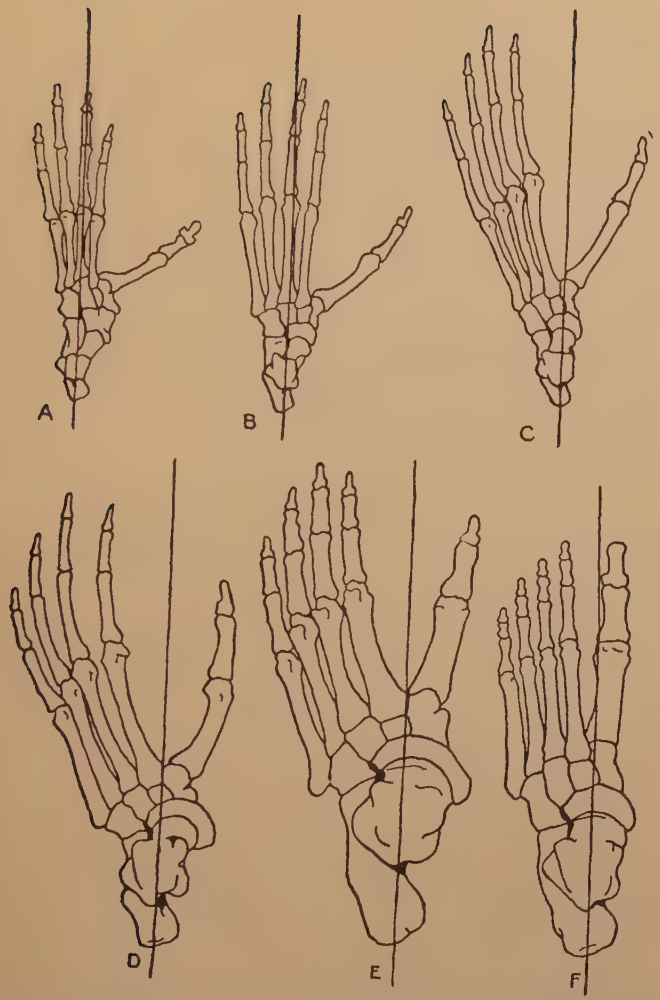

FIGURE 34. *The evolution of the human foot is suggested by these drawings of the pedal extremities of six primate skeletons: A, lemur; B, Old World monkey; C, gibbon; D, chimpanzee; E, gorilla; F, man.*

(AFTER DUDLEY J. MORTON.)

the task of locomotion and permitted their use as arms and hands.

Another marked advantage of life in the tree-tops was the premium placed upon good vision. Clear sight and accurate estimates of distance are prerequisite to continued existence for any individual who lives in that environment. The eyes of the lower mammals, situated on either side of a muzzle-like face, fail to give the stereoscopic vision which man enjoys. To the lower animals all objects appear without perspective in a single plane, but to the higher primates the picture presented by the eyes has three dimensions. The lower mammals depend more upon the sense of smell than upon the sense of sight, but most arboreal creatures have had to perfect their vision.

Thus, from arboreal, ape-like ancestors the lineage of mankind seems to be rather clearly indicated. The way is at last prepared for the advent of man himself in Quaternary time.

Chapter 4

Man's Ancestral Lineage

"Then light and swift through the jungle trees
We swung in our airy flights,
Or breathed in the balms of the fronded palms
In the hush of the moonless nights.
And oh what beautiful years were these
When our hearts clung each to each;
When life was filled and our senses thrilled
In the first faint dawn of speech!"

LANGDON SMITH IN EVOLUTION

No fossil material is available to serve as a basis for a precise description of man's ancestors as they appeared at the close of Tertiary and the opening of Quaternary time, the "Age of Mankind." Nevertheless the stage of development then attained may be rather definitely inferred from a comparison of middle Tertiary fossils with those of the Pleistocene Period. It was still far short of modern man. With

somewhat beast-like posture and with the shadow of the ape upon their faces, the prehuman beings of the late Pliocene must have eked out a precarious existence as they met in mortal combat the hyenas, tigers and other animals of the time. The intelligence which they possessed was adequate to permit the shaping of crude flint implements, a few of which are now on display in European museums, and beyond doubt they had already made some progress in the organization of clans or tribes for mutual protection. Plate VA gives a good idea of the customs of the time.

From this "almost human" stage of development the record leads onward through the Pleistocene Period to the advent of the existing species of humankind before its close. So many and so important are the milestones along this portion of the road which leads to man, that it is necessary to review in some detail the physical history of that time in order to have a suitable background for the story of human evolution.

During the Pleistocene Period the climate of the earth was repeatedly cooled so that regions which now enjoy a temperate or subtemperate climate were occupied by spreading ice sheets and perennial snow fields. This glacial period is frequently called "The Great Ice Age" although the actual refrigeration of the earth was not then as excessive as it had been during at least one other period of earth history. Nevertheless, from the human point of view this was

the *Great* Ice Age because the influence of its peculiar geologic events is even yet most profound.

The accompanying maps showing the extent of Pleistocene ice indicate that during this interval the whole of the Scandinavian Peninsula, most of the British Isles and much of Belgium, northern Ger-

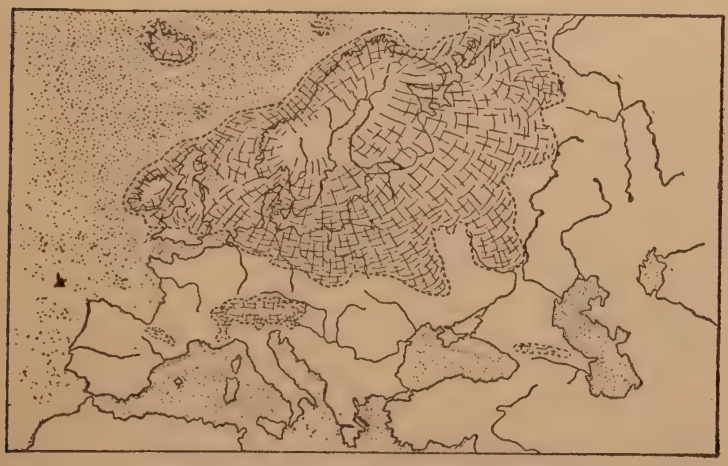

FIGURE 35. *The ice sheets which covered part of Europe during the Pleistocene glacial period occupied the shaded areas shown on this map.*

(AFTER WRIGHT, IN "THE QUATERNARY ICE AGE.")

many and western Russia were buried beneath a vast ice cap. At the same time the glaciers of the Alps were greatly expanded so that considerable areas of surrounding lowland were occupied by piedmont glaciers. Similarly in North America, the greater part of Canada, all of New England and much of the northern Mississippi Valley were covered with ice

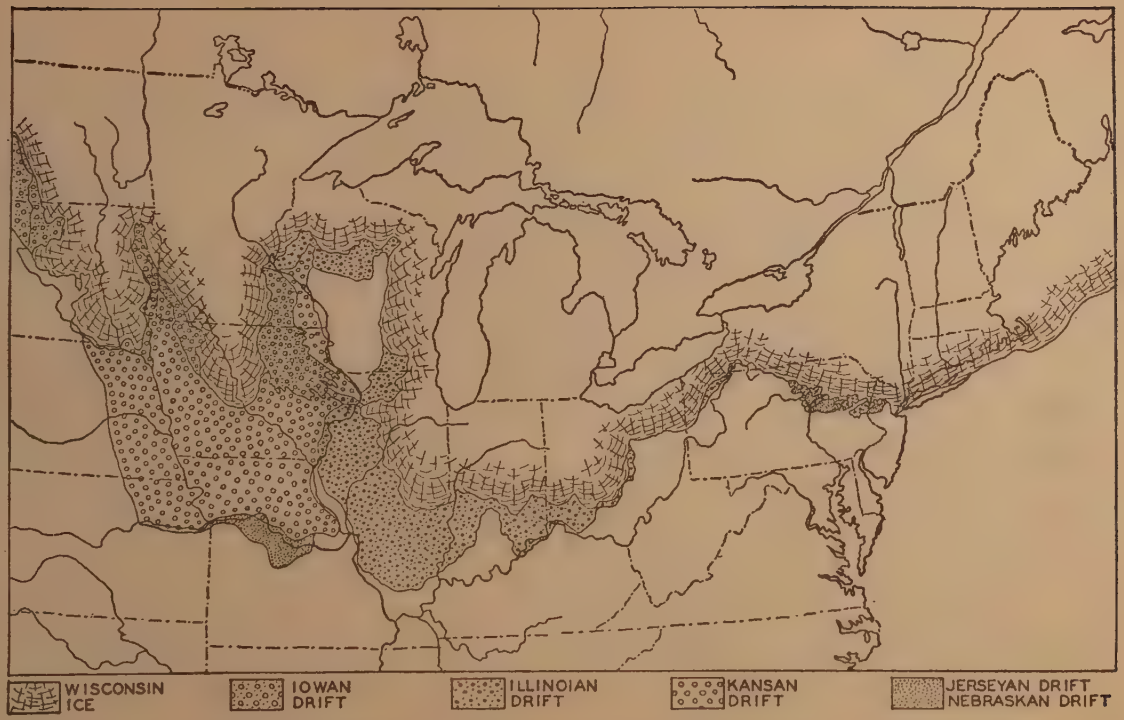

FIGURE 36. *During the Pleistocene Period the northeastern states were invaded by five successive ice sheets. The last of these, the Wisconsin ice sheet, is represented here as being at its maximum extent. The areas covered with drift of the preceding glacial stages are also shown.* (BASED ON MAPS PREPARED BY ERNST ANTEVS IN 1929.)

which must have averaged close to five thousand feet in thickness. Likewise, glaciers in the western mountains filled the valleys there and in places crept out upon the plains or plateaus beyond the mountain fronts.

Several times during the Pleistocene Period the climate of the earth was sufficiently refrigerated to cause the winter snows in northern latitudes and higher altitudes to remain unmelted from year to year. Gradually they accumulated in ever increasing depths until the pressure upon the lower part of the snow banks changed the delicate, flaky crystals into rounded granules of ice. This in turn was slowly compressed beneath the increasing overburden of ice granules and snow flakes, thus becoming compact glacial ice. The pressure increased from above until finally the lower part of the ice was unable to support its burden and the whole mass began to spread laterally or slide downhill. In Europe the ice moved northward, eastward, southward and westward from the center of the Scandinavian area and outward from the higher portions of the Alps. As long as the climate remained sufficiently cool the ice increased in volume and in area, but eventually the climatic pendulum was reversed, and with the returning warmth of the normal European climate the rate of melting at the margin of the ice increased until it equalled the forward movement due to the growth of the glacier. For a time the ice margin remained approximately stationary while successive cubic yards

of ice moved forward, melted, and deposited their load of pulverized rock débris plucked from the floor across which the ice had moved. Later the increasing warmth caused the ice edge to melt back still more rapidly, and the glaciers were reduced in size, most of them finally disappearing entirely.

This cycle of increasing cold followed by in-

EUROPE		NORTH AMERICA		APPROXIMATE DATES B.C
GLACIAL STAGES	INTERGLACIAL INTERVALS	GLACIAL STAGES	INTERGLACIAL INTERVALS	
				10,000
WÜRM	BÜHL		COCHRANE	
	AMMERSEE (WÜRM II)	WISCONSIN	PORT HURON (LATE)	25,000
	MAXIMUM (WÜRM I)		MAXIMUM (EARLY)	40,000
			PEORIAN	
	RISS-WÜRM	IOWAN		150,000
			SANGAMON	
RISS		ILLINOIAN		250,000 - 400,000
	MINDEL-RISS		YARMOUTH	
MINDEL		KANSAN		750,000 - 1,000,000
	GÜNZ-MINDEL		AFTONIAN	
GÜNZ		NEBRASKAN (JERSEYAN)		1,500,000 - 2,000,000

FIGURE 37. *The correlation of glacial stages in North America and Europe is not known with certainty, but the above table is probably fairly correct.*

creasing warmth has recurred at least four times in Europe during the Pleistocene Period which therefore is divided into four glacial episodes separated from each other by three interglacial intervals. The glacial stages are known as the Günz, Mindel, Riss and Würm. The first interglacial interval may be referred to as the Günz-Mindel, the second as the Mindel-Riss, etc.

The climax of ice expansion during the Würm glacial stage occurred about 40,000 years ago, as indicated by the rates of recession of waterfalls in post-glacial time and the seasonally banded clays in glacial and post-glacial lakes. Northern Germany and the British Isles were nearly or quite free from ice by the year 20,000 B.C., and the last of the ice caps melted away from Scandinavia about 8,000 years ago. There are no such accurate chronometers for determining the time which has elapsed since the earlier glacial stages of the Pleistocene. It is possible, however, to form a fairly accurate opinion concerning the length of those time intervals by comparing the amount of erosion of the several deposits of glacial drift. These would indicate that the Mindel-Riss or second interglacial interval was very much longer than either the first or third interglacial stages and that each of these was several times as long as the time which has elapsed since the Würm glaciers were at their maximum extent.

The effect of the advancing and retreating ice upon the animal and plant inhabitants of Europe can easily be imagined. Each ice advance was accompanied by an equatorward crowding of the several climatic zones and a southward migration of the European population. In close proximity to the ice front, wherever it was standing, dwelt the hairy mammoth and mastodon, the northern elk-deer and other creatures adapted for life in Arctic conditions. As the ice spread over northern Europe these animals advanced south-

ward into southern France and northern Spain. At the same time, the two-horned rhinoceros, the giant bison and the horse, as well as many other animals adapted to the existing climate of central Europe, were driven southward in the attempt to keep within the climatic zone which they preferred. Doubtless the barrier of the Mediterranean on the one side and that of ice and snow advancing from the other side formed a death-trap for many individuals. Certainly the Pleistocene Period proved a time of severe adversity for most land mammals and many species failed to live through it into Recent time. The great majority of the fossil mammals which occur in deposits of that age belong to species now extinct or at least no longer native to the European localities where the bones were found.

Fossils of these animals are comparatively abundant in the interglacial débris and in the lake and river deposits formed of materials liberated from the ice as it was melting. During each interglacial stage the warmth-loving creatures followed the retreating ice front northward and spread over central Europe much as they do today. Although human bones are extremely rare, enough have been found to serve as an accurate suggestion of the stages of development through which man was passing during the Great Ice Age. The association of the scanty human relics with petrified bones of the lower animals and with fossil plants, coupled with the study of the relations of these associated species to the deposits of the suc-

cessive glacial stages, makes possible the dating of the human remains.

The Pleistocene record of mankind includes not only fossil bones but also implements of flint and other articles manufactured of comparatively imperishable materials. The study of such artifacts will be reserved for the following chapter; here will be considered only the fossil remains of the human and prehuman inhabitants of the Old World during Pleistocene time.

One of the most important as well as the earliest of these was discovered near Piltdown, Sussex, England in 1911 and 1912 by Mr. Charles Dawson and Dr. A. Smith Woodward. The locality at Piltdown is only a few miles beyond the farthest reach of the last ice sheets of the Pleistocene Period. This is extremely fortunate for the reason that almost everywhere as the glacial ice advanced over the land it ploughed its way into the loose material and destroyed the record of earlier glacial time. Had Piltdown been covered by the ice sheet, the record of ancient humankind there as elsewhere would have been obliterated by the glacial plough.

The original find consisted of nine fragments of a man-like brain case or cranium and an imperfect lower jaw, bearing two molar teeth. A few months later a pair of nasal bones and a canine tooth were found in the same gravels. The associated remains of extinct species of elephant, mastodon, hippopotamus and beaver indicate an early Pleistocene age for the

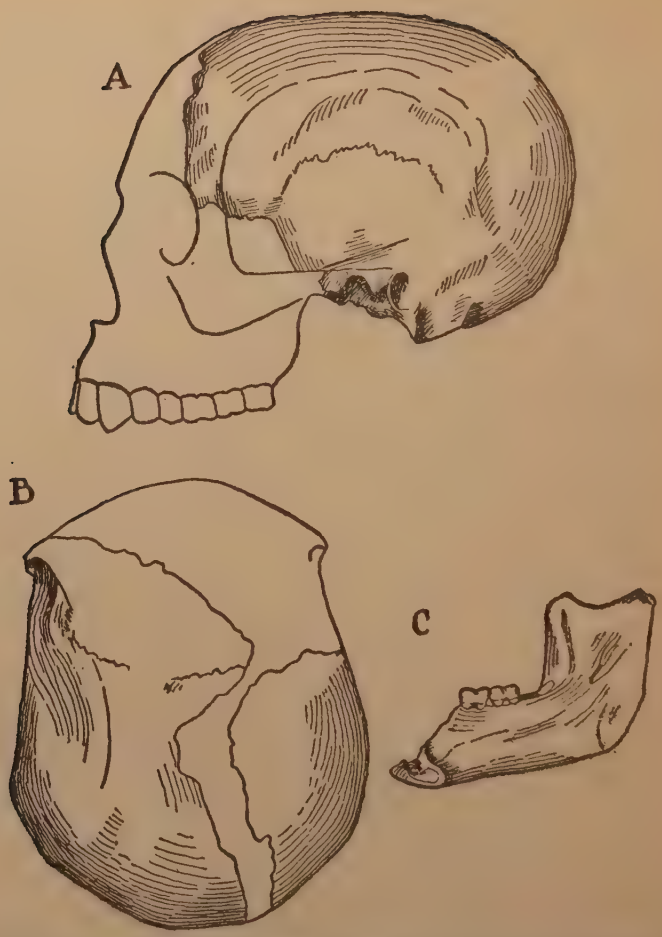

FIGURE 38. *The human remains found in the early Pleistocene gravel near Piltdown, Sussex, England, include fragments of the brain case and lower jaw. A is the skull, partially restored in outline, as viewed from the side; B is the same, as seen from above; C is the jaw fragment.*

(AFTER A. SMITH WOODWARD.)

entire gravel bed. The fragments of the cranium may easily be reconstructed into four pieces, but these four pieces may be fitted together in more than one way, depending upon whether one attempts to make the brain capacity as small or as large as possible and the head as round or as long as possible. In any event the skull must be that of a more primitive type of man than the modern European, with a brain capacity at least as small as that of the least intelligent of Australian aborigines. The jaw is distinctly ape-like.

For a long time a bitter discussion was waged among anthropologists and paleontologists concerning the correct interpretation to be placed upon these fragmentary fossils. Dr. Woodward believed from the first and has always maintained that the jaw and the skull fragments belonged to a single individual, even though they were scattered through several square yards of loose gravel and do not contain the points of articulation which if present might indicate unquestionably whether or not they belonged together in life. Accepting this view it would appear that there dwelt in southern England in early Pleistocene time a creature whose forehead and brain capacity were distinctly human, but whose lower jaw was notably ape-like. To this being Dr. Woodward has given the name Eoanthropus dawsoni, "the dawn man of Dawson."

Other experts who have examined the same specimens believe that the lower jaw is that of an extinct species of chimpanzee, whereas the skull fragments

belong to an early type of man. They would name the skull fragments Homo dawsoni to indicate their belief that this individual was only slightly different from modern man. And to the jaw they would apply the name Pan vetus to indicate their belief that it is a relic of an extinct species of chimpanzee.

While the controversy was still continuing, with the balance of opinion apparently veering toward Woodward's original conclusion that jaw and skull belonged to the same individual, additional specimens were found in similar gravels at a point about two miles distant from the site of the first discovery at Piltdown. This new material was discovered in 1917 and consists of another molar tooth, quite similar to those in the ape-like jaw originally discovered, and some fragments from the front and upper portion of the skull. One of these two skull fragments dupli-

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PLATE IV: A. *The gibbon is the least man-like of the great apes but displays all the essential anthropoid characteristics.* (PHOTOGRAPH FROM NEW YORK ZOOLOGICAL PARK.)

B. *The orang-utan has brain dimensions which in proportion to body size are about half those of the average man.* (PHOTOGRAPH FROM NEW YORK ZOOLOGICAL PARK.)

C. *The influence of the habit of brachiation in the development of the erect posture is well illustrated by this photograph of a young adult chimpanzee in the Primate Laboratory of Yale University.* (PHOTOGRAPH BY H. C. BINGHAM.)

D. *The short stubby thumb of the gorilla is in striking contrast to its long powerful fingers, but its hand as a whole is notably similar to that of man. Its beetling brow ridge and receding forehead are well displayed in this photograph.* (PHOTOGRAPH FROM NEW YORK ZOOLOGICAL PARK.)

A

B

C

D

cates a part of the original find and thus demonstrates the existence of at least two individuals possessing skulls of this particular type.

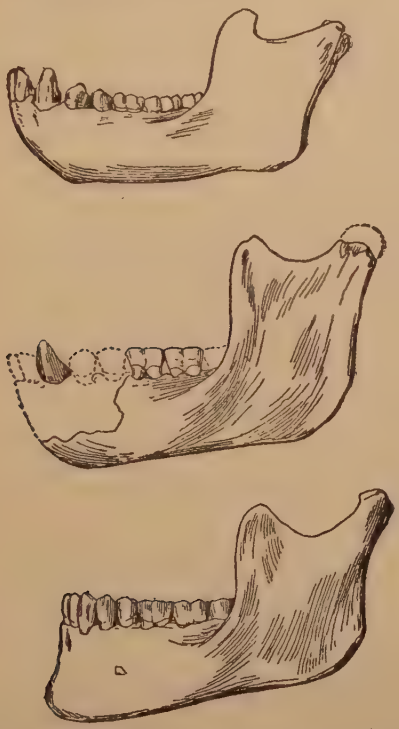

FIGURE 39. *The Piltdown jaw is in many respects intermediate between that of a chimpanzee, at the top, and that of modern man, at the bottom of this group of drawings.*
(AFTER A. SMITH WOODWARD.)

As it happens, fossil remains of chimpanzees are fully as rare in northwestern Europe as fossil remains of mankind. If the teeth and jaw fragment from Piltdown are correctly identified as belonging to Pan

vetus, they constitute the only specimens of this animal known from the whole of Europe. Nevertheless the coincidence of close proximity between the only known fossil chimpanzee and a distinctly human skull in the Piltdown gravel might have occurred. When this truly remarkable association is repeated, however, in the new material discovered two miles away, the case seems almost conclusive. The occurrence of two such coincidences is far beyond reason. It seems therefore necessary to conclude that Woodward's original interpretation of Eoanthropus dawsoni was correct and that jaw and skull actually belonged to the same individual.

Accepting this most reasonable interpretation of the observed facts, we may restore the head of the Piltdown man, as shown in Figure 40, and compare it with that of modern man. The absence of a chin and the great length of the lower jaw are conspicuous, and give a brutal aspect to the entire face. The frontal portion of the brain case is flat and low, and therefore in striking contrast to the highly vaulted appearance of that region among certain of the existing races of humankind. The molar teeth, although distinctly man-like in their general form, display the "Dryopithecus pattern" of the ridges on their grinding surface. In a very real sense, they are intermediate between the Dryopithecus type of molar and the human type, which is of course one of the reasons for the belief that Dryopithecus of the early Miocene

represents fairly precisely the ancestral stock from which man has evolved.

Clothing the restored head of Eoanthropus with flesh and skin, his appearance in life must have been somewhat as shown in Plate VII B. He was distinctly inferior to the most bestial of modern aborigines; the mark of the ape was stamped indelibly upon his countenance. And yet he was sufficiently intelligent

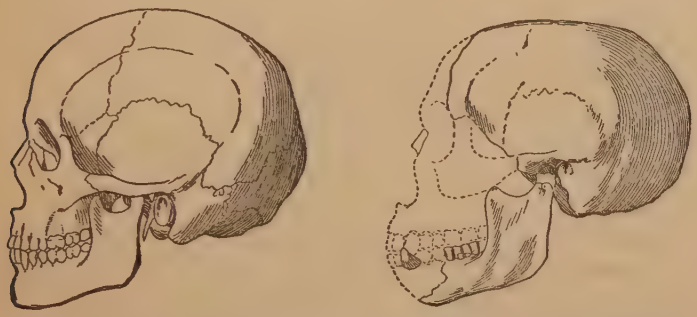

Figure 40. *The skull of Eoanthropus dawsoni from Piltdown. as restored at the right, is distinctly inferior to that of modern man, at the left.*

to manufacture implements for use in promoting his welfare. Two of the flint tools that have been found in the same gravel bed which yielded the fossil bones are shown in Figure 41. The "Dawn Man" discovered by Dawson had learned to "flake a flint to a cutting edge" or else some other, more intelligent being was living at the same time and place as he.

Fully as famous as Eoanthropus dawsoni in the annals of those who are attempting to decipher Mother Earth's diary is Pithecanthropus erectus, the

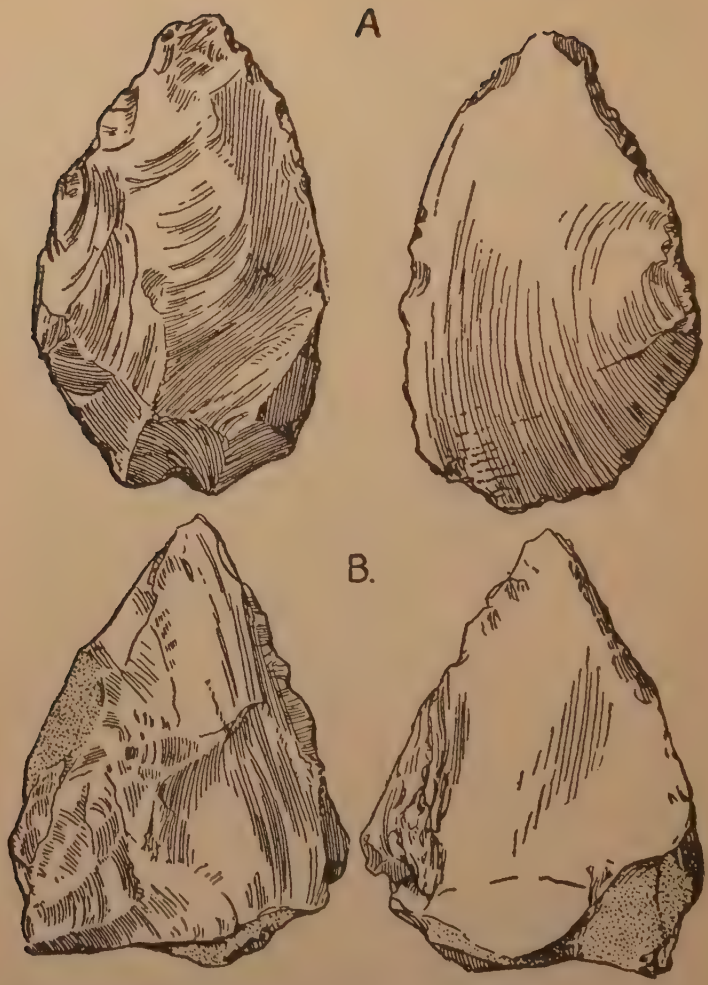

FIGURE 41. *Flint artifacts found in the Piltdown gravel indicate that Eoanthropus, or some unknown being of greater intelligence, flaked flints to a cutting edge.*
(AFTER A. SMITH WOODWARD.)

"ape-like man who stood erect." This species is based upon a skull cap, a leg bone and two molar teeth which were found by Eugene Dubois in the banks of Bengawan River near Trinil in Java in 1892. The fossils were in a gravel bed composed largely of fine volcanic débris which had been spread along the channels of an ancient river. With the man-like re-

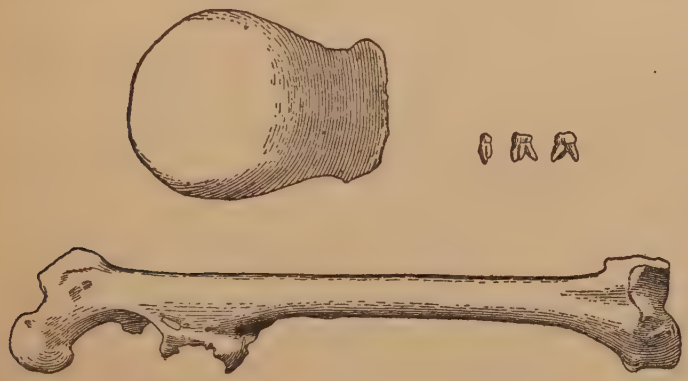

FIGURE 42. *The fossils from Trinil, Java, on which the extinct genus Pithecanthropus is based, consist of a skull cap, a femur and three teeth. The skull is viewed from above, with the forehead and eyebrow ridge at the right.*

mains were large numbers of similarly petrified bones of other animals, most of which are now extinct. These accompanying fossils and some fossil plants from overlying and underlying strata indicate that the deposit was formed either in early or middle Pleistocene time.

As shown in Figure 42, the skull cap displays characteristics that are distinctly intermediate be-

tween those of the great apes and of man. The petrified bones include the entire, solidly fused roof of the head extending from the region of the eyebrows to the base of the skull. In the accompanying illustration the view is from above, with the massive

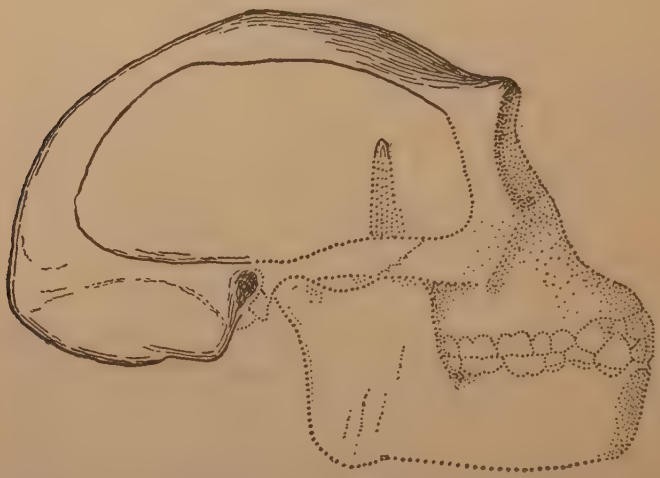

FIGURE 43. *As restored by Dubois, Pithecanthropus must have had a very ape-like appearance. In this drawing the known portion of the head, as viewed from the right side, is shown in solid lines, and the conjectural portion is stippled.*

eyebrow ridge at the right and the base of the skull at the left. The receding forehead and low vault of the brain case are even more conspicuously displayed in the profile view, Figure 43. The leg bone is the femur, the bone between hip and knee; its articulating surfaces at either end are so shaped as to indicate that its possessor stood in a fairly erect posture. Upon

the side of the femur, the bony tissues were abnormally developed; the leg had suffered some sort of injury which resulted in the peculiar growth shown in the illustration. Such pathologic conditions are not unusual, but they have nothing to do with the characteristics of the species to which the individual belongs.

Once more the inevitable question arises concerning the association of these separate portions of an incomplete and scattered skeleton. Did or did not the leg bone belong to the same individual that possessed this particular brain case? It is a question that cannot be answered with finality unless sometime a completely articulated skeleton is discovered in which this type of head is definitely connected, bone by bone, with this type of femur. In the meantime, the question must be considered on the basis of probabilities or left unanswered. Certainly, there is nothing incongruous in the inference that all the primate remains found in the Trinil beds are parts of a single skeleton; that inference harmonizes perfectly with all known facts concerning primate evolution and is in keeping with the theories based upon those facts. Moreover, the four fragments found by Dubois in 1892, and also another anthropoid tooth found later, were all in the same layer of sandy volcanic material and were within a few feet of each other. There is no duplication of parts; if more than one individual is represented it would be something of a coincidence that altogether different bones and teeth were pre-

served from each, and that the only known relics of each should have been deposited in such close proximity to the others. From the long controversy which has been waged concerning these unusually important specimens emerges the confident belief that Dubois was correct in his original conclusion that they represent a single individual.

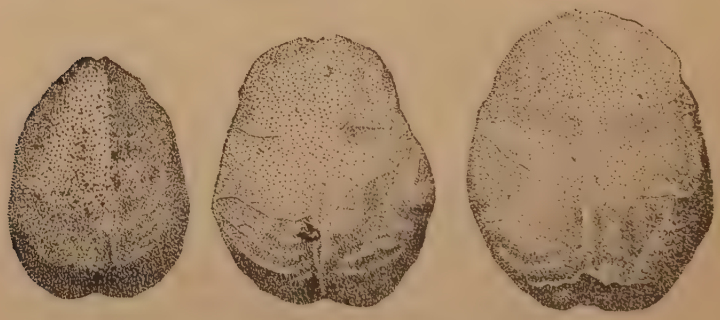

FIGURE 44. *The cast of the interior of the Pithecanthropus skull reveals the form and dimensions of the ape-man's brain; it is shown here with the brain of a large gorilla on its left and that of a member of the negroid race of Homo sapiens on its right. All three brains are viewed from above, with the brow region at the top of the drawings.*

(SKETCHED FROM PHOTOGRAPHS SUPPLIED BY AMERICAN MUSEUM OF NATURAL HISTORY.)

Nevertheless, this conclusion is still a matter of opinion, and it is therefore wise to base our estimate of the Java ape-man upon definitely ascertainable facts. Fortunately, the brain case is in such good condition that a cast of its interior can be made. This cast is a replica of the brain of this creature and reveals many details of brain form and structure. In

the accompanying illustration it is shown side by side with similar casts of the brain cavity of a gorilla and of a member of the existing Negroid race of human beings. Both in total size and in development of the occipital and parietal regions the Pithecanthropus brain is revealed as superior to that of the ape and quite inferior to that of the least intelligent of existing men. The designation "ape-man" is therefore accurately indicative of the position in the intellectual world, intermediate between apes and men, which must have been occupied by this Pleistocene inhabitant of Java.

The appearance of the ape-man's face is largely a matter of inference. Dubois's guess, shown in Figure 43, or that of the Belgian artist Mascré, shown in Figure 45, is as good as any. Although the shape of the lower jaw cannot be known with certainty because of the absence of any fragment thereof in the original collection, other discoveries seem to verify the interpretation that gives to it a distinctly ape-like aspect. A portion of a lower jaw containing the right first premolar tooth and a part of the root of the right canine tooth was found recently at Kedung Brubus, about 24 miles from Trinil, in gravel of the same geological level. The premolar tooth is small and resembles closely the premolar found in association with the skull cap at Trinil. In all probability this new material belongs to the same species; it is of course another individual. The inconspicuous fragment is especially important because it shows that the

chin was a little more prominent and man-like than the chins of apes, although displaying in general an ape-like form.

FIGURE 45. *The restoration of Pithecanthropus erectus, modelled by Mascré, does full justice to the mental ability indicated by the superiority of the ape-man's brain when compared with that of the most intelligent of the existing apes.*

Pithecanthropus is almost certainly not the ancestor of any living race of human beings; nevertheless he is correctly considered to represent an extinct

genus within the family Hominidæ. He is one of the many intermediate types which were developed in the great experiment which finally resulted in the perfecting of the human organism as we now know it. Many attempts at hominoid development must like this one have led into a *cul-de-sac*, before the open road which led to man was discovered. He may well have been a contemporary of the Piltdown "dawn man," although the Trinil beds are probably a little younger than those in Sussex from which the Piltdown remains were obtained. In any event he represents faithfully the South Asiatic type of man-like being which was living in about the same early Pleistocene stage as Eoanthropus, the European type. Certainly, the latter was somewhat closer to modern man in head form and brain development than was Pithecanthropus.

Another extinct member of the human family has recently been discovered among the early Pleistocene fossils of eastern Asia. At Chou Kou Tien, 40 miles from Peiping (Pekin), China, there are a number of rifts and caves in limestone, and, as at Taungs, South Africa, some of these are partly filled with rock débris and bones of animals which inhabited that region long ago. One of the rifts is a veritable menagerie of antiquity, and already more than four tons of fossil specimens have been transported from it to the Chinese National Museum. The bones include fragments and complete skeletons of bats, hyenas, sabre-tooth tigers, rhinoceros, bison, horses, antelopes,

mammoths, wolves and many other mammals. Some of the creatures apparently lived in the caves, others fell into open fissures in the rocks, and still others were in all probability dragged into the rift by hyenas and wolves or possibly even by the prehuman residents of the locality. Many of the bones are firmly cemented to the adjacent fragments by the deposit of lime from water which trickled through the rock débris and dripped into the cavities in the limestone.

During the year 1928, a number of fragments of hominoid jaws and teeth were discovered in this remarkably rich fossil locality. The teeth are distinctly human and the jaw fragments quite ape-like, a fact which goes far to corroborate the conclusion that the Piltdown skull and jaw are portions of a single individual. Because of these characteristics the species was named Sinanthropus pekinensis, the "man of Sin (China) from Pekin," by Black and Zdansky.

Inspired by the hope of finding more complete fossils where these fragments occurred, the Geological Survey of China proceeded with systematic excavations during the summer of 1929, under the supervision of W. C. Pei, a young Chinese geologist of that organization. On December 2, 1929, it was decided to suspend operations because of the cold wintry weather. That afternoon, Mr. Pei descended to the bottom of the pit to make a final survey of the cavity as his workmen were leaving it for the winter. Digging in the soft material which had been encountered at one side of the cave he uncovered

a curved bone which he at once recognized as part of the long-sought skull. The specimen, still partly embedded in the calcareous matrix of the cave deposit, was carefully wrapped in burlap and coated with plaster-of-Paris to protect it from harm on the cross-country trip to Peiping. There it was entrusted to Dr. Davidson Black of the Peiping Union Medical College who cleared away the matrix encrusting most of the bones.

Unlike the hominoid fossils previously discovered at Chou Kou Tien, this skull is in such perfect condition that little or no reconstruction will be needed. The lower face is largely missing, but the roof of the head, eye sockets, ear hole, back of the skull, and jaw sockets are intact. It is the skull of a young adult, probably female, in which the sutures binding together the various bones of the brain case are deep and not yet completely fused as they would become in maturity.

The brain capacity is about twenty-five per cent larger than that of Pithecanthropus, and there is a distinct frontal swelling in the region of the forehead. This, together with the development of slight parietal bosses, indicates a distinctly greater brain power than that possessed by the Java ape-man. At the same time the brow-ridges are excessively massive, and the skull is definitely inferior to any which has been referred to genus Homo. In all probability its owner possessed a very heavy ape-like lower jaw and face. Its characteristics are distinctly intermediate

between those of man and ape, and are in perfect harmony with those already inferred from the teeth and jaw fragments earlier discovered in the same cavities in the limestone.

Since there is no record of Pleistocene glaciation in this part of Asia the determination of the age of Sinanthropus is made possible only by the presence of well-known mammals in the same or related deposits. The study of the enormous amount of mammalian fossil material from Chou Kou Tien is now proceeding under the direction of Dr. C. C. Young and P. Teilhard de Chardin, and only tentative conclusions can be stated at this time. It appears, however, that "the filling of the cave with sand, gravel, rock débris and bones took place in a relatively short time, geologically speaking. Bones from the highest and lowest horizons all point to a very early Pleistocene age, corresponding with the onset of the first glacial stage of the Great Ice Age in Europe and North America."

It is hoped that further excavations will reveal a complete skeleton in which not only the bones of the face but those of the body and limbs are preserved in articulation with each other. The fragments already found belong to at least eight and possibly ten individuals. Probably the clefts and caves in the limestone cliff were used as shelters by these ancient prehuman beings. Here they were protected from the weather and were able to defend themselves from the attacks of sabre-toothed tigers and other members of the cat

family, while they "mumbled the bones of the slain" animals upon whose flesh they subsisted in part. If so, the chances of finding an undisturbed skeleton in some remote passageway in the network of caverns are fairly good.

Still a fourth extinct genus of the human family remains to be described. It is based upon a practically

FIGURE 46. *The skull of the Rhodesian "man", Scyphanthropus, is a remarkably fine specimen, with cranium and facial bones well preserved.*

complete skull, from which only the lower jaw is missing, and with which were associated the bones of the pelvis. These fossils are from Rhodesia, South Africa, and are probably of middle Pleistocene age, although they cannot be dated with any high degree of precision. The skull bones are extraordinarily thick and massive, the brain capacity is intermediate be-

tween that of Pithecanthropus and that of the least intelligent of modern races of mankind. There is a beetling brow-ridge from which the forehead slopes gently backward without providing much space for the frontal lobes of the brain. The face was ape-like in its proportions with an unusually great distance

Figure 47. *The pelvis of the Rhodesian "man", at the right, is notably different from that of modern man, at the left. Because the hip socket is so shaped as to indicate that this quasi-man must have had a stooping posture, he is named Scyphanthropus.*

between the base of the nose and the mouth. The pelvis which accompanied the skull is of peculiar significance. The socket into which the upper leg bone fits is shallow and so shaped as to indicate that the individual stood with a distinct crouch, in only a semi-erect posture. Hence, he has been given the name Scyphanthropus, the "stooping man."

Summarizing all these data, it may be observed that in early and middle Pleistocene time there lived at four widely separated localities four extinct genera of anthropoids, each of which was more or less intermediate between existing apes and man in brain capacity, head form and presumably features and posture. From England to Java and from Rhodesia to China the connected continents of Europe, Asia and Africa were inhabited by creatures who, though still distinctly ape-like, possessed mental resources adequate to indicate the dawn of human intelligence. The "age of mankind" had at last arrived. As indicated in the diagram, Figure 32, on page 94, Eoanthropus is closest of the four to the ancestral lineage of modern man.

The most ancient fossil which competent authorities consider to be sufficiently like modern man to merit reference to genus Homo is a lower jaw from a gravel pit at Mauer, near Heidelberg in Germany. The gravel bed in which it was found was probably deposited in middle Pleistocene time, during the long Mindel-Riss interglacial interval, but this chronological reference is only tentative, as the associated fossils are few. The human remains consist solely of the lower jaw, and in consequence it is likely that opinions will always vary as to its precise position in the "family tree of man." Nevertheless, the name Homo heidelbergensis, the "man of Heidelberg," seems altogether appropriate.

The Heidelberg jaw is fully equipped with dis-

tinctly human teeth which show by their worn condition the results of long use. Several are badly decayed; the possessor of this jaw must have suffered severely with the tooth-ache. The jaw bones are thick

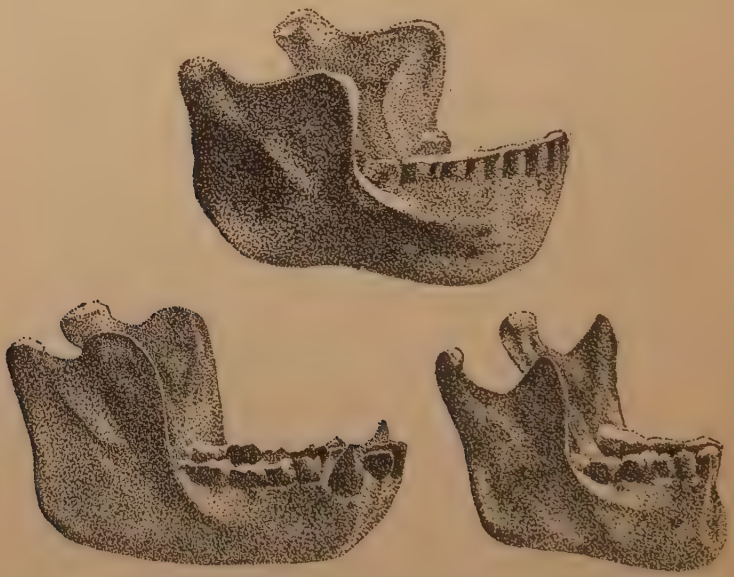

Figure 48. *The jaw of the Heidelberg man, above, may be compared with that of a chimpanzee, below at the left, and of a modern man, below at the right.*
(sketched from casts on display in the American Museum of Natural History.)

and broad, with abundant space for the attachment of powerful muscles. The sides of the jaw diverge backward in notable contrast to the parallel relation between the two lines of teeth on either side of the jaw of modern man. There is a faint suggestion of a

chin, and in general the shape of the jaw is intermediate between that of the chimpanzee and of modern man, with which it is compared in Figure 48.

Although the appearance of the Heidelberg man can only be inferred from such scanty evidence as this, the next record is quite adequate to indicate the entire body form and features of another extinct species of glacial man. At least a score of specimens, some of them quite complete skulls, others various parts of the skeleton, serve as the basis for Homo neandertalensis, the "man of Neandertal." The type specimen is from the hamlet bearing that name in northwestern Germany and consists of skull and lower jaw of a very elderly individual, so old that the teeth have almost all been lost and much of the jaw bone has been resorbed, as generally happens in late old age. Other specimens have been found at several localities in central and southern France, northern Italy and as far east as Czechoslovakia where some very remarkable discoveries have been made near Predmost within the last few years.

The brain capacity of Neandertal man was appreciably less than that of the existing Australoid race, but considerably more than that of any of the prehuman genera described in preceding paragraphs, with the possible exception of Eoanthropus whose brain may have been nearly or quite as bulky as the Neandertaler's. The forehead sloped rapidly backward from the massive overhanging brow-ridge above deep-set eyes. The receding chin and obliquely pro-

jecting frontal teeth gave a brute-like aspect to the face, and the head was carried far forward from the thick-set neck. The posture was not fully erect, but slightly stooping, with hunched shoulders. The accompanying reproductions of murals on display in the Logan Museum, Beloit, Wisconsin, give an accurate impression of the Neandertal stage of development and culture. Living in the rock shelters of the Dordogne plateau in central France, these vanished members of the human family became artisans of no mean ability, shaping flint implements for a great variety of purposes and using fire in a most intelligent way.

The Neandertalers were at the climax of their career during the third or Riss-Würm interglacial interval. Apparently they had migrated from the east into central and western Europe while the Riss glaciers were waning and then for a hundred thousand years or more enjoyed the comparatively genial climate of interglacial times. When the chill climate and bleak ice of the Würm glacial stage crept relentlessly upon them they were forced to give ground. It is not known whether they became extinct before the advent of the next type of human beings or whether the few lingering representatives of the species were slain by the more powerful invaders. Certainly no trace of Neandertal inheritance is discoverable among the present inhabitants of Europe.

The newcomers were the oldest known representatives of the existing human species, Homo sa-

piens. They arrived in central and western Europe at about the time when the Würm glaciers were at their maximum extent or just beginning to retreat; that is, about 20,000 to 40,000 years ago. The best known race is called Cro-Magnon, from a small French hamlet in the Dordogne region where several skeletons have been found in rock shelters or shallow caves eroded in the rugged cliffs. The Cro-Magnon and associated races were hunters, artists and artisans—splendidly proportioned, fine featured men with erect posture, high foreheads, well developed chins and brain capacity fully equal to that of the average European of today. Man, in the narrowest sense of the term, had at last made his appearance upon the earth.

It is a far cry from the ape-men with which the Pleistocene record begins to the Cro-Magnon men with which it closes. Much progress had been made; the well-known evolutionary method of "trial and error" had been abundantly vindicated. Intellect and coöperative ideals were firmly established as powerful determining factors among the offspring of the earth.

Chapter 5

Artists and Artisans of the Great Ice Age

> *"It is the capacity of organic form to gather and store experience, which demarks it from the inorganic."*
> N. S. SHALER

The mental ability and motivating ideals of the various types of humankind whose fossil bones are believed to be of Pleistocene age, cannot be adequately judged from a study of those bones alone. Intelligence is not proportional to the quantity of brains possessed by an individual, nor is the quality of one's ideals indicated by any known skeletal feature. Nevertheless it is safe to infer that the more closely an extinct species of anthropoid resembles modern man in brain dimensions and skull shape, the more similar were its mental operations and motives to those of Homo sapiens. The inference is not merely reasonable; it is supported by many known facts. What a man makes indicates fairly well what he thinks; how a man lives reveals quite accurately his intellectual processes.

Our knowledge of glacial man in the Old World is based in large part upon recently discovered relics

of antiquity which include articles which he manufactured, tools which he used in his work, implements which he fashioned and works of art which he achieved. These, even more than his petrified bones and teeth, proclaim his attainments and disclose the level to which human nature had ascended. Both industry and art began to flourish as the human hand was freed from the tasks of locomotion and the anthropoid brain reached dimensions approximating those of the least intelligent of existing races.

Using the hands to manufacture implements is one of the characteristics which distinguish man from all other creatures. Squirrels, and many other animals, use their fore limbs to convey food to their mouths. Monkeys, and certain other anthropoids, pick up stones or sticks and may possibly use them as weapons, although this use of such objects is doubted by many observers. Some of the large apes are known to gather sticks and twigs for "nests" which they construct with their hands in the crotch of a tree or in a clump of underbrush. But no animal other than man is known to fashion implements which he may later use in some constructive or destructive activity.

This essential characteristic of mankind depends upon two anatomical features: the hand and the brain. The development of the brain during the Cenozoic Era is indicated by the increasing size of the braincase in the various primates known as fossils in the rocks of that era. Each of the extinct genera referred to the family Hominidæ is known to have had a brain

capacity superior to that of any existing ape, and before the end of the Pleistocene Period there dwelt in Europe the Cro-Magnon race of Homo sapiens, with a brain fully equal in dimensions to that of the average man of today. But no bones of the hand pertaining to any extinct genus of hominoids have ever been found fossilized. Not until the advent of Homo neandertalensis is the record of skeletal parts complete enough to indicate directly the structure of the fore limbs, and apparently the Neandertalers had completely human hands.

The evolution of the hand must therefore be inferred from the record of the things which it has fashioned and from a comparison of its modern structure with that of existing apes and pre-hominoid fossils. Contrary to popular ideas, man's hand is a very generalized rather than a highly specialized portion of his body. It still retains all five digits, the number with which the primitive placental mammals began their career. Some of the primates have reduced the number of digits to four, the tapir and the rhinoceros have advanced to the three-toed stage, cattle and deer have two toes, and the horse has reached the ultimate reduction to a single toe. Evolutionary progress in these and many other mammalian strains is marked by decrease in the number of digits on hands and feet; in this respect, man has made no progress whatsoever.

The great apes are in the same class as man so far as number of fingers and toes is concerned, but their hands are more highly specialized than the hand of

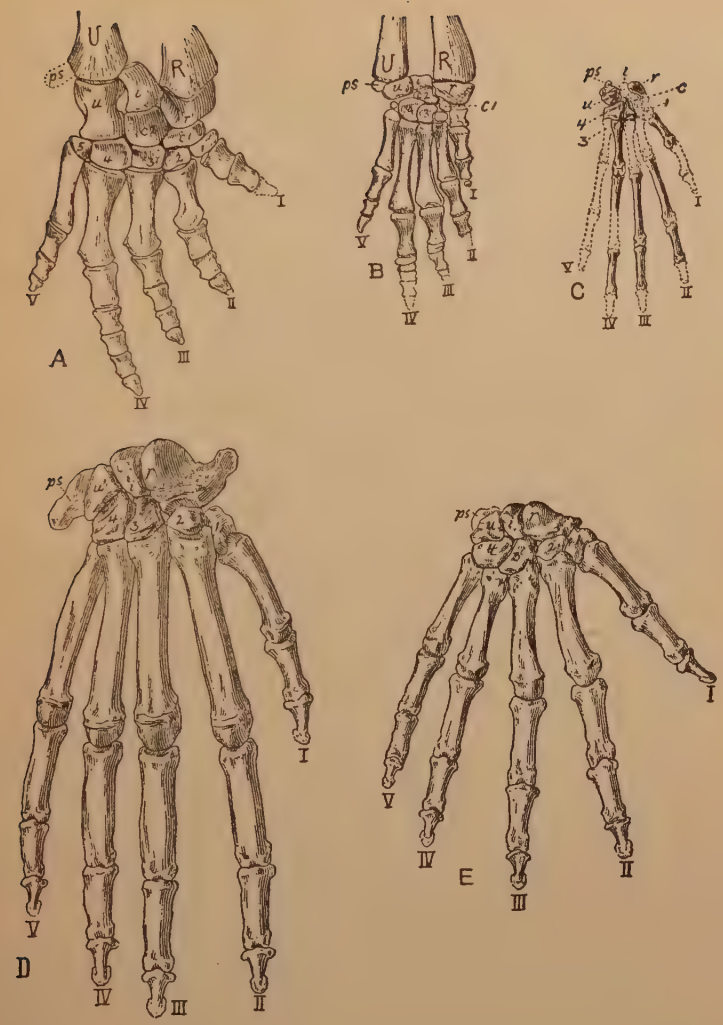

FIGURE 49. *The evolution of the human hand is suggested by these drawings of manual extremities: A, mammal-like reptile; B, more advanced mammal-like reptile; C, Notharctus; D, gorilla; E, man.*

(FROM GREGORY, "THE UPRIGHT POSTURE OF MAN.")

man. The habit of brachiation has noticeably affected the bones and muscles of the thumb and fingers, and these are now especially well adapted for their task of holding the suspended body as it is swung from branch to branch. But whereas the human gymnast grips the travelling rings firmly with his thumb as he swings through the air, the gibbon, chimpanzee and gorilla use the thumb very little or not at all. Instead, they curve their long fingers over the branch and use them as hooks by which they hang suspended. In consequence the thumb is comparatively short and inflexible. In many respects, the human hand is today nearer in its structure to that of the primitive, early Tertiary Notharctus than is the hand of any modern ape.

Only man can oppose the ball of his thumb to the tip of each of his four fingers, as he pleases. When an ape grasps a stick or stone, he holds it clumsily by bending his fingers down against the palm of his hand. It is almost impossible for him to pick up an object with thumb and fingers as a man may readily do. Man's peculiar ability in this regard is an inheritance from early Tertiary time, unspoiled by too long a sojourn in the tree-tops.

The gorilla is a fairly close second to man with respect to facility of hand but, like the other apes, is lacking in brain-power. In order to manufacture implements there must be the unique combination of adept hand and designing brain, which is found solely in the human family.

FIGURE 50. *The gorilla, John Daniel, was repeatedly psychoanalyzed during his life in captivity, and after his death (from natural causes) his skin was mounted and is now on display in the American Museum of Natural History.*

Hand and brain were sufficiently developed before the end of the Miocene period to permit the first known industrial activity involving tools or implements. The artisans of that ancient time are entirely unknown; presumably they were creatures less human than Eoanthropus but superior to any known ape. Their presence is indicated by flints, artificially and intentionally shaped, which have been found in the upper Miocene and Pliocene rocks of France and England. Apparently the first imperishable material used by mankind in the manufacture of tools or implements was stone, and best of all stones for his purpose was flint. For literally millions of years our prehuman and human ancestors were in the "Stone Age" of industry and culture.

Stone implements found in Tertiary rocks are known as "eoliths," or "dawn stones," to distinguish them from the "paleoliths" of the "Old Stone Age" and the "neoliths" of the "New Stone Age." Without exception the eoliths display the crudest of workmanship; the technique of the stone-worker was just dawning. For the most part they are pebbles chipped along one side to give a semblance of blade-like form, or shaped roughly at one end to make an extremely crude awl.

So casual is the flaking of some of the supposed eoliths that it may well be doubted whether they are the result of any intentional design rather than the accidental fracturing which may occur entirely apart from human activity. There are many ways in which

FIGURE 51. *Many eoliths consist of flint nodules flaked to a sharp edge along one side. These were presumably grasped in the hand and used as a chopping knife.*
(FROM WILDER, "MAN'S PREHISTORIC PAST.")

a pebble of brittle flint may be chipped quite naturally, without the agency of human hands. If a mass of gravel is involved in a landslide, some of the pebbles will be broken as they are dashed against each other in the downhill rush. Swept along the bed of a swift stream, pebbles are occasionally hurled by the water with sufficient force to chip flakes from projecting points. Even lying quietly on the surface of the ground, they are subject to expansion and contraction with every change of temperature, and this may cause chips to break away from their sides. Occasionally, the result of such natural processes has been erroneously interpreted as an artifact made by a primitive craftsman. Indeed, there are many specimens which cannot be classified with certainty; they may have been artificially shaped for some purpose, but they might just as well have been formed quite naturally. There are, however, certain flints, such as those represented in Figure 52, which beyond question were flaked by successive blows, carefully and intelligently related to each other. These cannot be imitated by natural processes, but are unmistakably the work of primitive artisans. They are not found in rocks older than the Miocene.

The eolithic type of implement is found associated with both paleolithic and neolithic artifacts in Pleistocene and Recent deposits. At every stage in human development, the individual must learn anew the arts of his time. The youthful novice repeats in a few years the long process of gradual improvement by

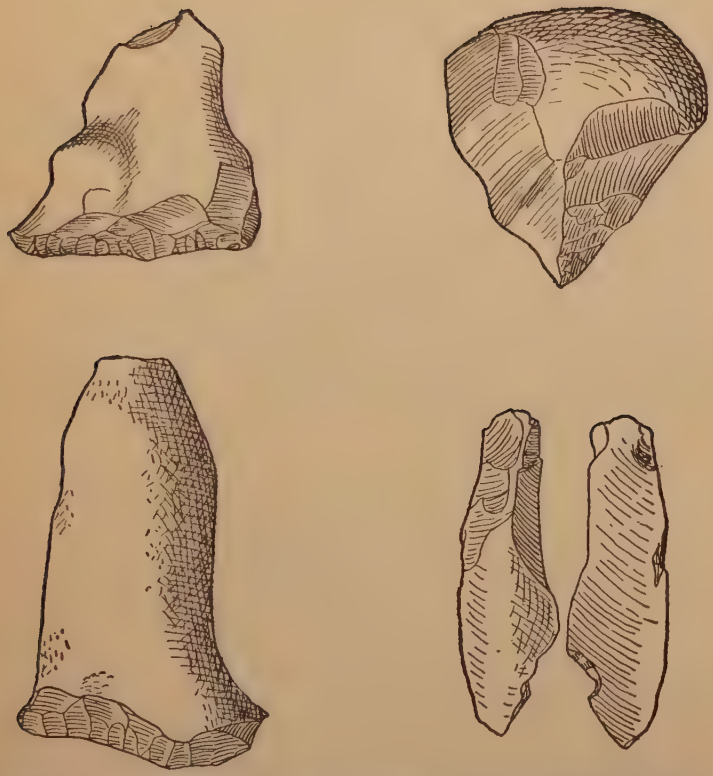

FIGURE 52. *Among the chipped flints from the upper Tertiary rocks of England and France there are a few unquestionable artifacts, showing a definite design on the part of the agency which flaked the edge or point. Others, like the stone, two views of which appear in the lower right corner of this group, are of doubtful origin.*

which his adult ancestors attained the skill which he is trying to emulate. His early attempts at shaping a flint skinning knife or javelin point may yield results no better than the best which his eolithic predecessors were able to achieve. Or again, the expert craftsman among the Neandertalers or Cro-Magnons must often have discovered, after striking a few blows upon a flint pebble, that it contained concealed cracks or flaws which rendered it unfit for the particular tool which he had in mind. Such stones, tossed aside by the workmen of any time, may resemble the finished product of the eolithic stage. They are, however, not eoliths, but "rejects."

The paleolithic age is almost precisely co-extensive with the Pleistocene Period. It therefore covers the time during which the extinct genera and species of the family Hominidæ were waxing and waning in Europe, Asia and Africa. Before its close the ape-men, dawn-men and semi-men had been replaced by Homo sapiens, as represented by the Cro-Magnon and allied races. During this long interval of time there

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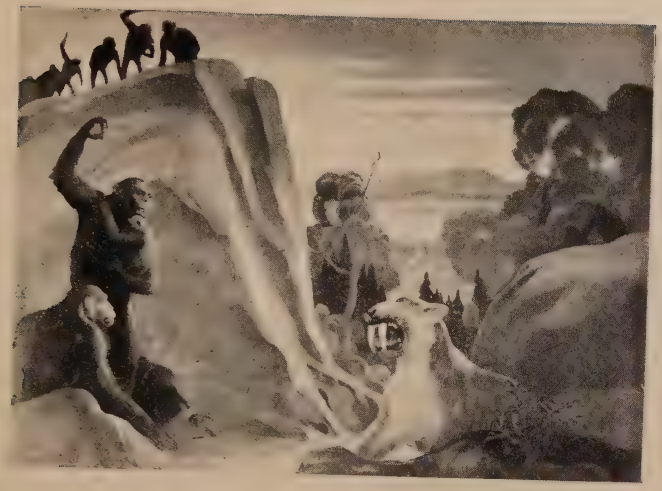
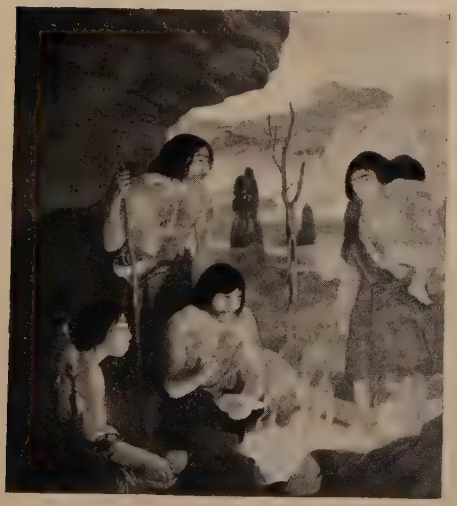
PLATE V: A. *Although no fossil bones of the late Tertiary ancestors of mankind are available for study, a fairly accurate notion of the status of the human family at that far-off time may be obtained from a comparison of the middle Tertiary and earliest Quaternary relics. These served as a guide for the artist, Mr. John Norton, when painting this mural for the Logan Museum at Beloit College, Beloit, Wisconsin.*

B. *Another of Mr. Norton's murals in the Logan Museum represents a Neandertal family in a rock shelter such as those found in the Dordogne region in France. One of the group is making a core implement of flint by the percussion method.*



A



B

was much improvement in the art of flaking flints, great expansion in the variety of uses to which stone implements could be put, and many changes in customs among the successive inhabitants of the eastern hemisphere. The task of deciphering the record of these activities of the earlier representatives of the hu-

Figure 53. *The Dordogne River and its larger tributaries in south central France flow in steep-walled, flat-floored valleys with numerous shallow caves or rock shelters at the foot of the cliffs.*

man family is pre-eminently the function of the student of prehistoric archeology.

One of the localities which has been most thoroughly investigated and has yielded most important information is the Dordogne region in central France. It is a country of great beauty, somewhat remote from ordinary tourist routes and yet by no means inaccessible. Into a broad low plateau, the Dordogne

River and its several tributaries have cut steep-walled, flat-floored valleys. Most of the plateau is composed of horizontal layers of sandstone and sandy limestone which form sheer cliffs overlooking the fertile bottom-lands. At many places great alcoves have been eroded by the curving streams which have cut beneath overhanging ledges of rock and then have abandoned their earlier courses to leave shallow caves near the base of the valley walls. Other caves and grottoes have been formed by the dissolving action of water trickling down through the rock from the plateau surface to emerge as springs along the side of the valleys. These caverns are generally slender winding passage-ways which lead back scores or hundreds of feet into the cliffs.

From time immemorial the crescent-shaped alcoves with their sheltering roofs of overhanging rock have been a refuge for mankind. During the middle ages and even in modern time, the inhabitants of the region built their homes beneath the rocky ledges to take advantage of the shelter thus provided. In some of them, the Roman soldiers camped when Julius Caesar was discovering that "all Gaul is divided into three parts." Still earlier they were occupied by the cave men of the paleolithic age.

The record of these successive occupants of the caves and rock shelters is partially preserved in the débris strewn upon their floors. Occasionally, the river which had eroded the alcove would return during an unusual flood season and leave a deposit of stream-

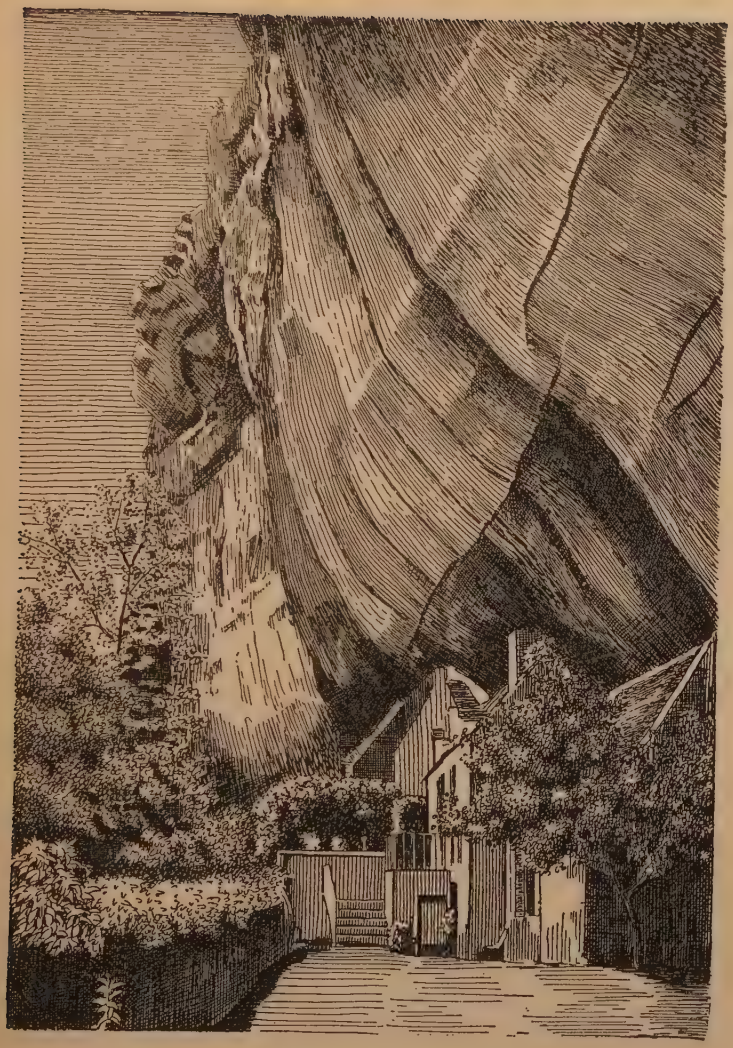


FIGURE 54. *The sheltered alcove at the foot of the cliff at Laugerie-Basse in the Dordogne plateau was occupied for many thousands of years by prehistoric races before the modern Frenchmen built their homes beneath the overhanging ledge of rock.*

worn gravel and silt. Frequently, fragments of rock would break from the underside of the overhanging ledges and fall to the ground beneath. Still more frequently, the wind sweeping across the valley floor would deposit dust, silt and sand within the shelter. In such ways, the floors of these caves have been built progressively higher until today some of them contain layers of accumulated débris, which aggregate fifteen or twenty feet in thickness.

As the archeologist digs downward into the successive layers of débris he turns backward the pages of history. At one level he may encounter the charred remains of ancient campfires surrounded by the mumbled bones of animals slain for food, with an occasional flint weapon or other implement left behind by the departed gourmands. Still lower he may uncover a trampled, hard-packed surface, which had earlier been the cave floor, and on it he may find still older relics of human occupation. Thus, the physical relations of the artifact-bearing strata indicate the sequence of the human cultures which they represent.

As a rule the paleoliths from the higher levels are superior in their workmanship to those from lower levels, but this is not always the case. Occasionally, the better craftsmen were followed by tribes with poorer technique. In the main, however, the succession is distinctly progressive, so that the later paleolithic implements are indicative of a higher intelligence and greater skill than that implied by the earlier paleoliths.

In the terrace gravels along the banks of many rivers in western Europe there are artifacts still older than those found at the lowest levels in the caves and rock shelters. The oldest of these in France, Belgium, England and Spain are known as pre-Chellean, because their stratigraphic position reveals them to be older than the Chellean, a culture found in somewhat younger deposits in valleys of central France.

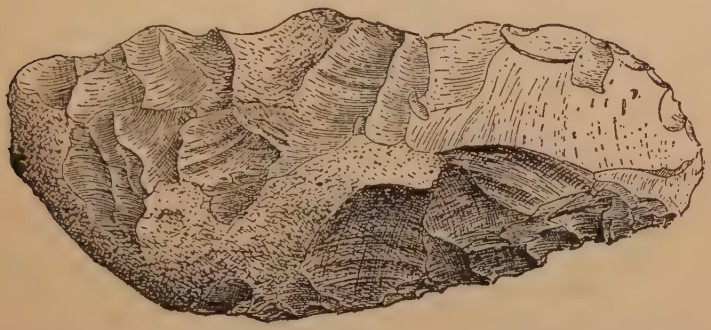


Figure 55. *This Pre-Chellean flint "knife" was found in the base of the gravel in the third terrace of the Somme Valley.* (after commont.)

The typical Chellean implement was a sort of axe or cleaver, held firmly in the hand and used either for striking a blow or for cutting and scraping a piece of wood or the flesh, sinews and hide of an animal. It was a rather large piece of flint, shaped wholly by percussion. In its manufacture, the rough flint nodule or water-worn pebble was hammered into shape by blows from another piece of flint or from a hammerstone, such as a quartzite cobble picked up from the bed of a stream. Occasionally, such cobblestones are

found in the ancient workshops with their surfaces marked and marred by the impact, frequently repeated during the manufacturing process. Crude

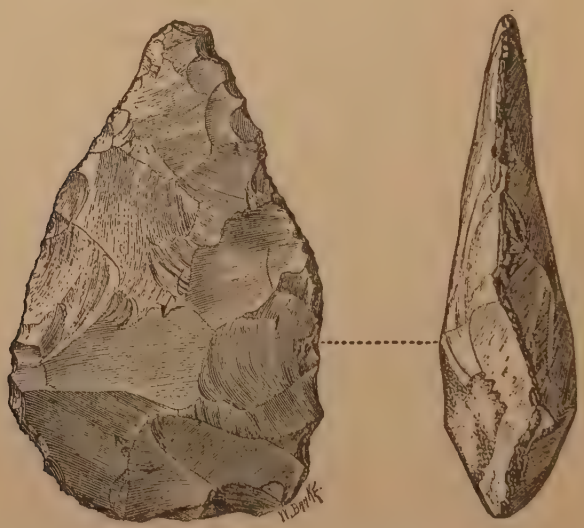


FIGURE 56. *The Chellean cleaver was roughly chipped on both its faces, and the base was thick and rounded so that it could be held conveniently in the hand. It was used variously for cleaving, chopping, scraping, skinning, splitting, sawing or puncturing. This specimen, from the pit at Montières, Somme, France, is in the Yale University Collection.*

(FROM MAC CURDY, "HUMAN ORIGINS".)

though the Chellean artifacts are, their shaping requires considerable skill, as anyone may discover if he tries to imitate their workmanship.

The Chellean culture was followed by the Acheulian with its greater variety of implements and a slightly better technique in the flaking of flints. The

Acheulian axe seems designed for use with some sort of handle, in either or both of the ways indicated in Figure 59. Almost all of the Acheulian artifacts, like the pre-Chellean and Chellean, are core implements, fashioned from a nodule of flint by removing flakes or chips from its surface until the desired form had

FIGURE 57. *Quartzite hammerstones were frequently used by paleolithic artisans in their workshops. This much-used stone from the cave of La Combe, Dordogne, France, is now in the Yale University Collection.*
(FROM MAC CURDY, "HUMAN ORIGINS.")

been achieved. This was accomplished mainly by percussion, but it is likely that some of the early paleolithic artisans used fire to aid them in their work. Flint expands and contracts notably when heated or cooled, and the accidental splintering of the brittle mineral in the edge of a campfire must have suggested very early in human history the possibility of using heat in the shaping of the larger tools.

In sharp contrast to the more primitive core implements are the flake implements, formed by working up the edges of the flakes removed from the core. In middle and late paleolithic time these became the more common type and the core implements were relatively scarce. The newer type of flake implement

FIGURE 58. *The Acheulian cleaver was thinner than the Chellean, and its edges were less sinuous.*

began gradually to appear in Acheulian time, but was still quite rare at its close.

With the advent of the Mousterian industry, however, the flake implements become much more abundant. Although the workmanship is still somewhat crude, it is apparent that the Mousterian artisans were using flints for a great variety of purposes.

Some of the many skulls and skeletons of Homo neandertalensis are associated with Mousterian tools and weapons, and it is therefore known that the Neandertalers were for a time at the level of culture indicated by this type of artifact.

Figure 59. *The Acheulian axe may have been mounted in a handle in either of these two ways.*
(from Wilder, "Man's Prehistoric Past.")

The Mousterian industry was followed by a new type, known as Aurignacian, in which many of the flake implements were long, narrow, thin and delicately worked. Scrapers with specially curved points were worked to a knife-edge along one side and pur-

posely blunted along the other margin so as to be held conveniently in the hand. Core scrapers and notched tools were also fashioned. Bone implements were in-

FIGURE 60. *Mousterian flint implements include points, scrapers and disks, sharpened around the edges by pressure flaking. The two pieces of bone near the center of this group of specimens are scarred, through use as chopping blocks or in pressing off the tiny flakes from the edges of the flint tools.*
(AFTER CAPITAN AND PEYRONY.)

troduced in the form of awls, arrow-straighteners and polishers, and before the end of Aurignacian time these became quite common. In this industry the trimming of flints by percussion reached its highest development, and in all probability the Aurignacian

artifacts represent a finer technique than the Neandertalers were able to achieve.

With the advent of the next type in the sequence of human cultures, another new technique is ap-

FIGURE 61. *Aurignacian flint blades were commonly curved and sharpened along only one margin so that they could be held safely in the hand when in use.*
(AFTER L'ABBÉ H. BREUIL.)

parent. The Solutrean industry is characterized by very fine, thin tools, carefully worked on all surfaces and finished by the process of pressure-flaking. In this process, small thin flakes are removed from the flint

by pressing near the edge with a bone tool or with another piece of flint, rather than by striking with a hammerstone. The perfection of the "laurel-leaf"

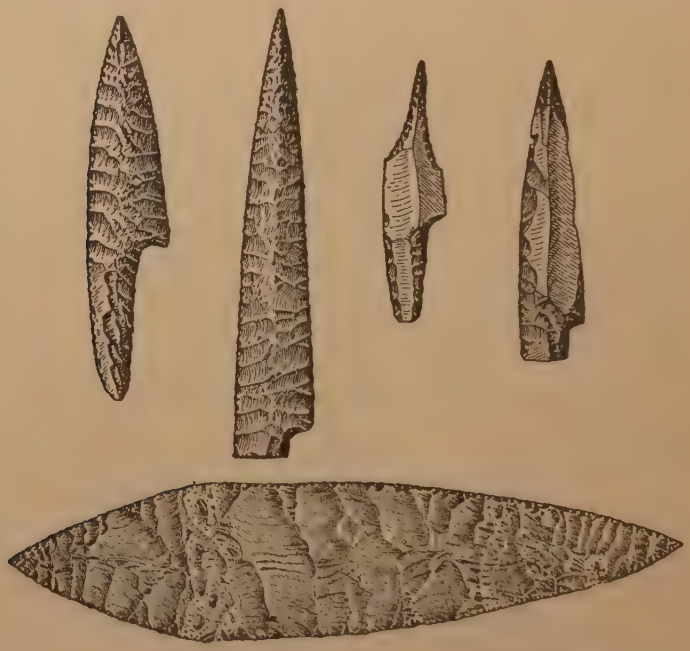


FIGURE 62. *Solutrean flint blades and points were delicately and marvellously fashioned. The "laurel-leaf" blade at the bottom of this group is nearly fourteen inches long and less than a half inch thick.*

(AFTER DE MORTILLET.)

blades, points, gravers and notched arrow or javelin heads is truly amazing.

The distribution of the Solutrean artifacts indicates that the people who made them were immigrants from the east into western Europe, where they

settled in the plains rather than in the mountainous localities. Apparently they mingled with some of the Aurignacians who learned from them the new art of pressure-flaking. Still later, most of the Solutrean aborigines withdrew eastward, presumably keeping pace with a climatic change which occurred at this

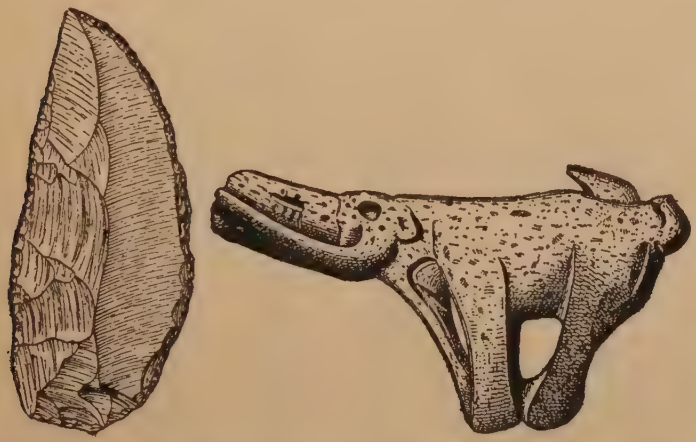


FIGURE 63. *The Magdalenian flint graver, at the left, is reminiscent of the Aurignacian type of artifact, but the Magdalenian dart thrower of reindeer horn, at the right, is distinctly new, almost modernistic in its artistry.*
(AFTER L'ABBÉ H. BREUIL.)

time and caused coniferous woodlands to displace the open prairies in western Europe. The Solutreans were pre-eminently hunters of wild horses and cattle, and, when their prey retreated eastward before the advancing forests to localities where steppes and grassy plains persisted, they likewise withdrew.

Peake and Fleure suggest that "during the period

of Solutrean domination many of the Aurignacians fled to the fastnesses of the Pyrenees or other mountain regions, where flint was relatively scarce, and

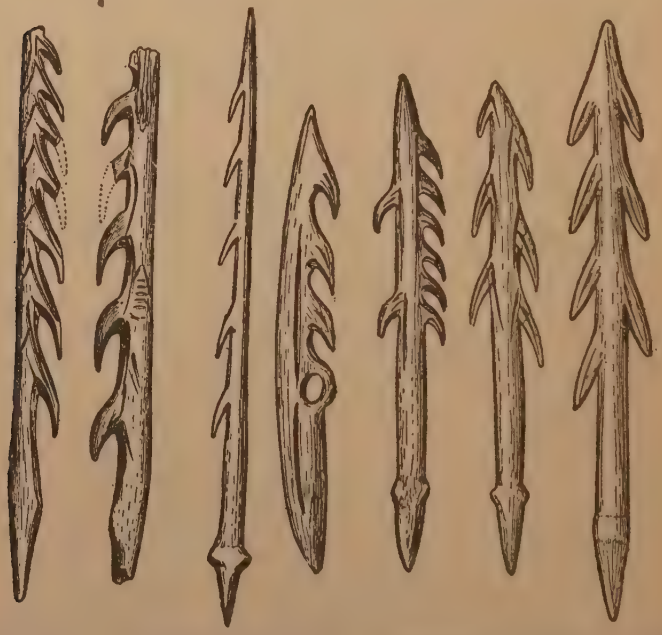


FIGURE 64. *Magdalenian harpoons of reindeer horn show a definite progress through at least three stages of workmanship. The four at the left are from the second stage, in which barbs were cut on one side of the harpoon, and the three at the right are from the third stage, in which there is a double row of long sharp barbs.*

(AFTER L'ABBÉ H. BREUIL.)

where they were, from lack of this material, compelled to develop an industry of bone and horn. On the departure of the Solutreans they returned to their old hunting grounds," where in the meantime the for-

ests had grown up and climatic conditions had notably changed. Certainly the Magdalenian industry which followed the Solutrean in western Europe shows far closer relationship to the Aurignacian culture than to that which immediately preceded it. Moreover, the Magdalenian artisans spent much more time and energy in the fashioning of bone implements than in the working of flint tools. The notched harpoons of bone and the decorated staves of reindeer horn which came from their workshops are a radical innovation, and reveal new though not necessarily better customs.

Although at some places there are indications of a transition from Mousterian to Aurignacian implements, there is nearly everywhere a marked change from the older to the newer forms. The Aurignacian, Solutrean and Magdalenian cultures are unquestionably the result of the arrival in western Europe of a new type of human being, the Cro-Magnon and associated races of Homo sapiens. They mark the advent of "modern" man as distinct from archaic species, such as Homo neandertalensis. It is convenient to refer to them as upper paleolithic industries to distinguish them from the middle and lower paleolithic cultures which had preceded them.

They in turn were superseded by still more modern industries to which the term neolithic is ordinarily applied. During the "New Stone Age" the artisans learned the technique of grinding and polishing the surfaces and edges of their implements and began to

use many other materials beside flint, bone and horn. And here the geologist gives place to the historian; although it is not illogical to expand the science of geology to include the record of "fossil man" during the Pleistocene Period, it is apparent that the special technique of that science is of little avail when one comes to the task of deciphering the last few thousand years of human history.

There remains, however, the difficult and important problem of relating the successive stages of human culture to the sequence of glacial and interglacial stages which comprise Pleistocene time. Only by discovering that relationship can we find a basis for estimating the lapse of time in years since each of the paleolithic industries was in its heyday.

Most of the caves and shelters in which paleolithic artifacts have been found in Europe and Asia are well beyond the reach of the glaciers of the Great Ice Age. The few which are known within the area covered by the ice sheets and Alpine glaciers of the Würm stage, the last of the four great ice advances, contain only the remains of upper paleolithic industries. These shelters were occupied after the ice had withdrawn from their vicinity during the waning stages of the last glacial episode, and it is therefore possible to date the three upper paleolithic cultures with a fair degree of accuracy. The Aurignacian industry flourished in western Europe from about 15,000 B.C. to about 10,000 B.C.; the Solutrean approxi-

mately from 10,000 B.C. to 9,500 B.C.; the Magdalenian from 9,500 B.C. to 6,500 B.C.

Fortunately, remains of the several paleolithic industries have been found in many of the terraces

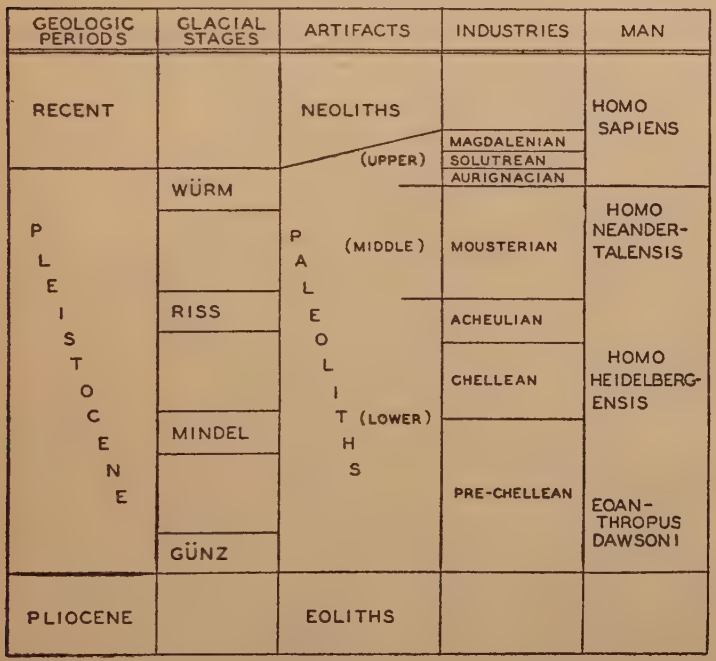


FIGURE 65. *Correlation table of paleolithic cultures and glacial stages in western Europe.*

which overlook the bottom-lands of the Somme and other valleys in France and Germany. Flint implements, the workmanship of which reveals the cultures to which they belong, are not infrequently recovered from the gravel beds of which these terraces

are composed. At many places it can be demonstrated that the artifacts must be of the same age as the gravel terrace in which they were entombed. And the terraces may be traced upstream until their relations to the glacial moraines are evident. Some of the terraces are composed of material liberated from the melting ice and washed down the valley from the ice front. Others were constructed in interglacial intervals. The geologic story establishes the relationship between early human history and the sequence of climatic changes during Pleistocene time.

The Mousterian industry is characteristic of the Riss-Würm interglacial interval and continued in western Europe even after the climax of ice advance during the Würm glacial stage. The Neandertalers responsible for this typical middle paleolithic culture survived the Würm advance, but, shortly after the glaciers of that stage began to retreat, they were displaced by the Aurignacians. Acheulian artifacts were fashioned, either by the earlier Neandertalers or by a pre-Neandertal species, during the latter part of the Mindel-Riss interglacial interval, and while the Riss glaciers were advancing and retreating. Earlier in the Mindel-Riss interval the Chellean industry had flourished for a very long time. The pre-Chellean cultures were developed during the Günz glacial stage, the Günz-Mindel interglacial interval and the Mindel glacial stage. With the exception of Eoanthropus dawsoni, no skeletal remains of the early human beings responsible for the Chellean and pre-Chellean arti-

facts have as yet been found in close association with those early paleoliths.

Paleolithic man was not only an artisan; he was also an artist. Many of the later paleolithic bone implements are ornamented with skilfully engraved figures of animals, and the mural decorations in certain

FIGURE 66. *The first of the paleolithic artists made no attempt to show perspective in their drawings, but the intent to represent a mammoth is obvious in this Aurignacian sketch from the cavern of Castillo, Santander, Spain.*

(AFTER ALCALDE DEL RIO, BREUIL AND SIERRA.)

of the caves in France and Spain are of a high order of merit. The age of the decorated artifacts is determined in precisely the same way as that of undecorated tools, but it is not always possible to relate the mural art with certainty to the appropriate stage in paleolithic history. Apparently, the Aurignacians and Magdalenians were most artistically inclined. The

Mousterians have left no record of any creative impulse other than strictly utilitarian, while the Solutreans seem to have been so busily engaged in the pursuit of game that they had little time for artistic expression.

The mural drawings in the caves occupied by upper paleolithic man are almost exclusively outline

FIGURE 67. *The two-horned rhinoceros is today extinct in Europe, but its fossil remains indicate that the paleolithic artist who drew this mural in the cavern of Font-de-Gaume, Dordogne, France, at least twelve thousand years ago, was a faithful portrayer of contemporary life.*
(AFTER L'ABBÉ H. BREUIL.)

sketches of the wild animals which they hunted. Most of the drawings are deeply graved in the yielding rock of the cavern wall or roof, some are in bas-relief, and a few are paintings made by daubing colored clay, charcoal or ochre upon a smoothed rock surface. Among the animals represented is the two-horned or woolly rhinoceros, a creature which today is entirely extinct, but whose fossil remains are not uncommon

in glacial and associated deposits. Similarly there are the hairy mammoth, likewise extinct now, and the reindeer and bison which no longer inhabit western Europe. All these must have been familiar figures to the paleolithic artists.

FIGURE 68. *The hairy mammoth was also a contemporary of paleolithic man when ice sheets still covered Scandinavia and the climate of central France was much colder than it is today. This engraving, deeply incised in a wall of the cave of Les Combarelles, Dordogne, France, is spirited and lifelike, although not very accurate in its proportions.*
(AFTER L'ABBÉ H. BREUIL.)

As would be expected, the thousands of years of upper paleolithic time witnessed a notable advance in artistic expression. Most of the earlier murals and portable engravings are extremely crude. The mammoth is shown with only two legs and without per-

spective, like a shadow cast upon a screen. Later, the rudiments of perspective appear as the artist strove to differentiate the farther from the nearer legs. Still later are the splendid polychromes such as have been found near Altamira in northern Spain and in the

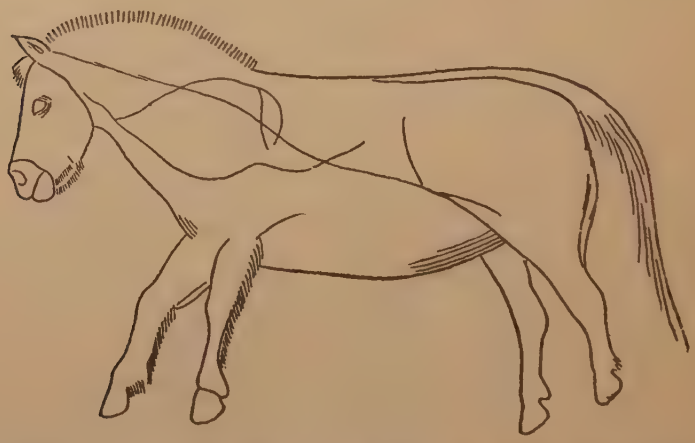


Figure 69. *This portrayal of the wild horse shows noteworthy progress in the art of representing body form, when compared with figure 66.*

cavern of Font-de-Gaume, Dordogne, France. Finally, just before the close of paleolithic time, the artists began to group their figures as though they were attempting to record specific incidents which they wished to commemorate. Typical of this class of murals is the stag hunt depicted in the "Cueva del Mas d'en Josef" in northern Spain.

The motive in the artist's mind when he sketched a mural of this last sort is obvious. To preserve a rec-

ord of memorable events and thus to "store experience" is a characteristic human trait. But the purpose in the mind of the earlier caveman when he engraved upon the cave wall the outline of a solitary mammoth, bison, or horse is not so obvious. The modern mind can only speculate concerning what the actual motive must have been. There are, however,

FIGURE 70. *Before the close of the Magdalenian stage of paleolithic culture, this lively representation of a stag hunt was painted on a rock face beneath an overhanging ledge in eastern Spain.* (AFTER OBERMAIER.)

certain analogies between the paleolithic art of the Great Ice Age and similar attempts at pictorial representation made by the more primitive aborigines of the present day. Furthermore, certain characteristics of the drawings help us to reach rather definite conclusions. In some, a heart is represented on the animal's body at the proper position so that a javelin blow at that place would pierce the vital organ itself.

In others, darts and javelins are shown piercing the animal's body at strategic points.

The aborigines whose artistic attempts are preserved in the caves of France and Spain lived in an age of magic, and like all primitive folk they were exceedingly superstitious. Presumably the drawings on the cave walls indicate the cult of the "medicine man." A hunter planning to start on the chase would go into the cave with the medicine man and participate in a mysterious ritual which presumably would involve the hurling of his javelin or spear at the pictorial representation of the animal he desired to kill. Thus he would gain magical skill and be all the more efficient in the hunt which he was planning. Or again, the idea might well have lodged in the mind of the Cro-Magnon man that the spirits dwelling in the various wild animals would be pleased at his recognition of their presence by the pictures on the cave wall. In consequence the gratified spirits would send many mammoths, bison, or wild horses into the locality where they might be found by the huntsmen.

If these are the correct interpretations of the artistic impulse which began to blossom forth in late paleolithic time, we must admit that then as now most art had its utilitarian purpose.

The belief in a spirit world is clearly indicated by many practices and customs known to have pertained to the Cro-Magnon and associated races. Many of the human skeletons of upper paleolithic age have been found in such relations to their surroundings as

to indicate that the body had been buried with ceremony and ritual. Tools, weapons and jars of food were placed in the grave to assist and nourish the spirit of the departed warrior as it journeyed to the "Happy Hunting Ground." Even earlier in human history, when the Neandertal man was at the height of the Mousterian culture, there is more than a suggestion that religion was already dawning. The Neandertal skeleton found at La Chapelle-aux-Saints was a ceremonial interment, and the corpse had been accompanied by implements of the usual Mousterian type. Furthermore, several of the Neandertal skulls, including this particular one, display a large hole in one side of the cranium. The skull was fractured and broken by a blow from some blunt instrument, either at the moment of death or after the death of the individual. So many of these skulls are thus broken that it is scarcely likely to be the result of accident. There are in existence today certain primitive tribes, the members of which are accustomed to break holes in the skulls of their dead "to release the spirit so that it may escape from the body and start for some distant abode." In all probability the Neandertalers had a similar belief.

If these are correct interpretations of the observed facts, it is apparent that belief in the continuity of life after death and in the reality of a spirit world is actually older than the existing human species. Such ideas date back at least 50,000 and probably more than 100,000 years into the Great Ice Age.

Chapter 6

The First Families of America

"Men, my brothers, men the workers, ever reaping something new;
That which they have done but earnest of the things that they shall do."

ALFRED TENNYSON IN LOCKSLEY HALL

THE STIMULATING record of the remarkable progress made by mankind in Europe, Asia and Africa during the Great Ice Age stirs the patriotic American to enquire what was happening in the New World at that same time. Was the infancy of the human race entirely confined to those three continents or did other lands share in the achievements which marked the dawn of art and industry? Must we conclude beyond question that the cradle of humanity was actually located in the Old World, or is there any basis for the hope that elsewhere an extinct genus of "semi-man" or a primitive species of genus Homo may have left a record which still awaits discovery?

Australia may be promptly ruled out of consideration. That continent was wholly isolated from all

other lands throughout the entire Cenozoic Era. Until man crossed the sea in rafts or boats, the only placental mammals which lived there were those which in some way spanned the oceanic barriers. This feat can be accomplished in several ways, even by land mammals which unlike the bat are barred from the air lanes. A small animal, or the tiny young of a large species, may be carried in the talons of a bird of prey and dropped upon a distant island before its life is snuffed out. Occasionally, great rafts of fallen trees accumulate along a river channel and may be swept far out to sea during a spring freshet or other flood; these may transport an inhabitant of one continent or island to a distant shore and safely deposit it there. Either method is, of course, most precarious; not often will the voyager arrive in safety. Moreover, unless the wayfarer is a pregnant female, the solitary immigrant must find another member of the same or a closely allied species, with which to mate, if the exotic strain is to be perpetuated in the new area.

It is therefore not surprising to find that the Tertiary mammals of Australia consisted almost exclusively of egg-laying and marsupial forms. These had reached that continent during the Mesozoic Era, when it was connected by land bridges with Asia, long before mammalian evolution had advanced to the placental stage. Then, before the Cretaceous placentals of the northern hemisphere had found time to send an expeditionary force to so distant an outpost, the bridges were destroyed and Australia was saved from

invasion. It became a place of refuge for the non-placental mammals which elsewhere were never able to make much progress in the face of the overwhelming numbers and power of the more efficient placentals. In that safe haven the marsupials flourished, deploying into many carnivorous as well as herbivorous strains, of which the kangaroo happens to be the most famous. No matter how favorable might have been the geographic environment provided by Australia, there could be no evolution toward mankind upon that continent. Only from the shrew-like Cretaceous placentals could the first primates evolve; only from the first primates could anthropoids descend; only from the anthropoid stock could man arise. Environment is helpless without the right sort of germ plasm; heredity is necessarily a prerequisite for evolution.

But the two Americas present a very different situation. Primates lived here during the Eocene Period, and in succeeding periods of Tertiary time some of them evolved into the platyrrhine monkeys of Central and South America. At almost any time during the Cenozoic Era the anthropoids of Asia could have made their way dry-shod across land connections between that continent and North America. The elephant family made the journey from northern Africa across Asia to North America during the Oligocene and Miocene periods, and the anthropoids might well have done the same. It is therefore no waste of time to search among the Tertiary rocks of the Americas for anthropoid fossils.

On the other hand, the failure to find such fossils in North America, coupled with the known record of anthropoid progress in the Old World, fully justifies the conclusion that man is not, geologically speaking, a native of the western hemisphere. In the present state of knowledge it appears that mankind must have migrated hither from Europe or Asia. The only questions worth considering are those pertaining to the geologic date of his arrival and the biologic level to which he had then ascended. Did man reach North America before or during the Great Ice Age, or is his residence here entirely post-glacial? Did the first families of America belong to the species Homo sapiens or did some other hominoid species or genus, now extinct, dwell here before the modern type of humankind had been perfected?

The two questions are intimately related. Early Pleistocene representatives of the human family in Europe, Asia and Africa were without exception so different from modern man that their reference to extinct genera is scarcely questioned. Middle Pleistocene man-like beings in the Old World possessed skull characteristics which set them apart from modern man as extinct species of genus Homo. Since we know that Homo sapiens first arrived in Europe during the Würm glacial stage, it would be most surprising for him to have reached North America before the equivalent Wisconsin glacial stage here. Although the true scientist must always be ready to accept newly discovered facts, no matter how astonishing they are, it is

only logical for him to demand unquestionable evidence before assenting to conclusions which fail to harmonize with the data already at hand. In this case, the burden of proof that any pre-Wisconsin inhabitant of America was a member of the species Homo sapiens would rest very heavily upon the person who made such an assertion.

Nevertheless, consideration of the topic "Glacial Man in America" cannot be as brief as the classical essay on "The Snakes of Ireland," which consisted of the one sentence, "There are no snakes in Ireland." The antiquity of man in America is sufficiently great to project his history back at least into the closing stages of the glacial period.

When the New World of the Americas became known to the inhabitants of western Europe in the last decade of the fifteenth century and the first few decades of the sixteenth, they looked upon the "Red Indians" of the Atlantic seaboard, with their pitiable shelters, their stone implements, scanty use of metals and semi-nomadic life, as veritable barbarians. They promptly concluded that America was the home of primitive savages with a culture far inferior to the civilization of the east. Only in the last few years has it become known that during the first millennium of the Christian Era the inhabitants of the western hemisphere were nearly as diversified in their habits, customs and culture as were their contemporaries in Europe and Asia. The splendor of certain pre-Columbian civilizations in America, the technique of the Ameri-

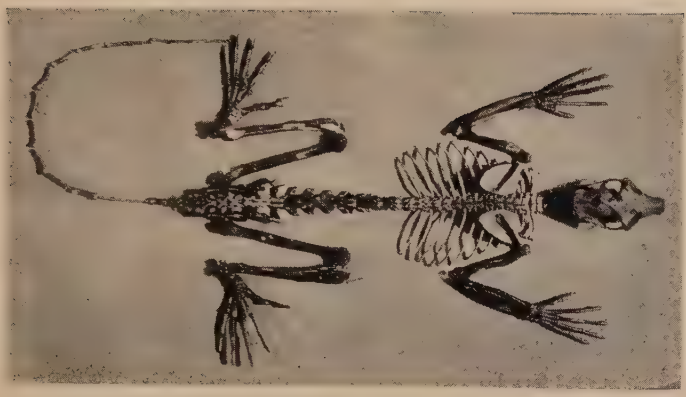
FIGURE 71. *Serpent Mound, in southern Ohio, is one of the largest and best preserved of the many effigy mounds left by the moundbuilders in the eastern part of the Mississippi Valley.*

can artisan and the intelligence of the native scholars have only lately received the appreciation which they deserve.

The broad fertile lowlands of the Ohio and Mississippi valleys and the coastal plain of Georgia and Florida were formerly homes of a moundbuilding race. Forts, cemeteries and ceremonial structures of that people have long been objects of great interest to the student of prehistoric civilizations. Some of the great earthworks which still stand as a monument to this vanished race were constructed in imitation of a snake or other animal; some were in geometric patterns, a square, an octagon, or a circle, constructed with a remarkable precision which testifies to someone's skill in surveying as well as in design. The great circle near Newark, Ohio, portions of which now serve admirably as bunkers on the golf course of the "Mound-builders Country Club," is 1054 feet in diameter and nowhere departs more than four feet from

PLATE VI: A. *Notharctus is the best known of the generalized primates which dwelt in North America in early Tertiary time. The skeleton shown here is nearly complete and indicates that this primitive lemuroid was not far removed from the strain which led eventually to man.*
(PHOTOGRAPH FROM AMERICAN MUSEUM OF NATURAL HISTORY.)

B. *This photograph of the skull of Sinanthropus pekinensis, found by W. C. Pei at Chou Kou Tien in 1929, was made in Peiping before the petrified bones had been entirely removed from the field wrappings. The view shows the profile of the head, from the massive brow ridge at the right, over the receding forehead and the top of the skull, to the back of the head at the left.*
(PHOTOGRAPH BY DR. DAVIDSON BLACK; COURTESY OF PROFESSOR C. W. BROWN OF BROWN UNIVERSITY.)



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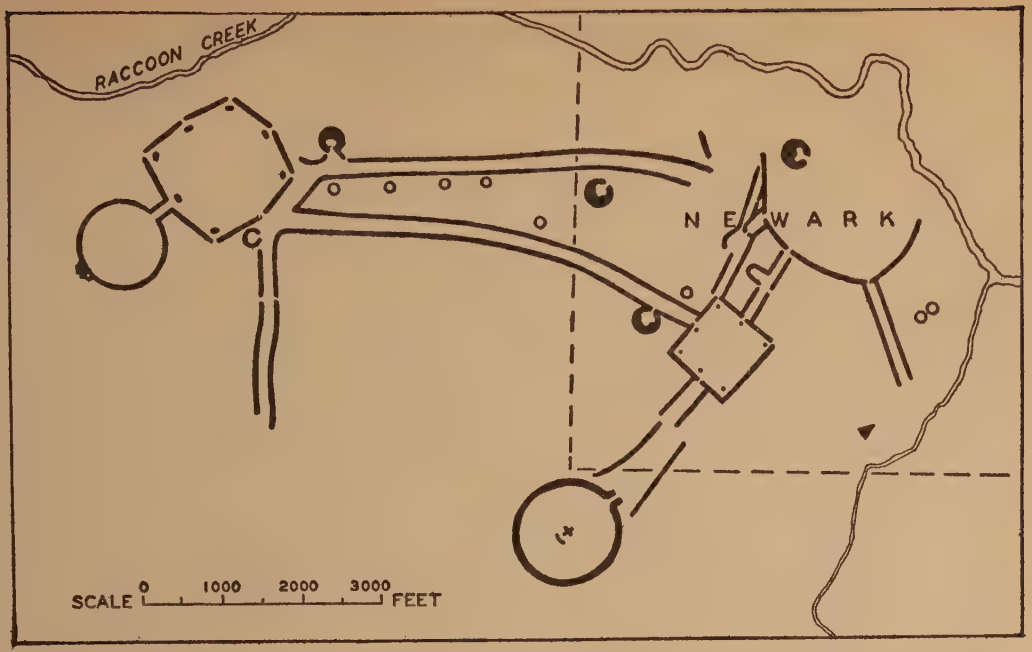


FIGURE 72. *The mounds near Newark, Ohio, are surprisingly accurate in their geometric design and were presumably the site of great conclaves of a religious, economic or political nature, or a combination of all three, when the civilization of the moundbuilders was at its height, a few centuries ago.*

perfect circularity. Other mounds were truncated pyramids or great platforms providing a safe refuge on a low river-plain during times of flood. Still others were tombs in which the dead were laid away, accompanied by ornaments, weapons, ceremonial implements and pottery, which give a fair impression of the ability of the artisans of the time.

In recent years the excavations made in these mounds have revealed many interesting facts concerning the moundbuilders. Some, like the Fisher Mounds, sixty miles from Chicago, had been inhabited by at least three successive groups of people, separated from each other by an unknown number of centuries. The oldest and most primitive group had buried their dead, accompanied only by crude flint implements, and then had covered the graves with a heap of earth. Sometime later another group buried their dead in overlying layers of earth brought from the adjacent country to make a lofty mound. These people placed well-made implements of copper and stone, as well as pottery jars of food, in the graves. Their skulls were quite different in shape from those of their predecessors, but both types were unmistakably of the Homo sapiens configuration. Later the mound was built still higher by a third group of inhabitants in whose graves silver buckles, glass and china beads, and bits of European cloth have been found. These were obviously Indians who lived so recently that they had made contact with the newcomers from the eastern hemisphere.

The moundbuilders have often been referred to as people of great antiquity, a statement for which there is no justification. With possibly a few exceptions, they all manufactured a neolithic type of polished stone implement. The yielding earth of which the mounds are built shows little erosion anywhere. Doubtless some of the older mounds date back into the centuries immediately preceding the Christian Era, but nothing suggests that even the most ancient are more than three or four thousand years old. In comparison with the records of man in the rock shelters of central France, they are relatively recent relics.

Little is known of the early life of the nomadic Indians of the western plains. Their failure to develop permanent habitations or ceremonial structures reduced their opportunity for contributing prehistoric records of their ancient activities. The great variety of languages and dialects, which they displayed when they first came in contact with white men, implies a considerable span of time for their occupancy of the area, but probably not more than two or three thousand years.

In striking contrast, the plateaus and canyons or the southwestern states, Mexico and Central America were the homes of settled communities whose historical record may now be traced back beyond the dawn of the Christian Era. When the Spanish conquistadores worked their way northwestward from the Gulf of Mexico in the sixteenth century, they encountered the Pueblo Indians, some of whose descendants are

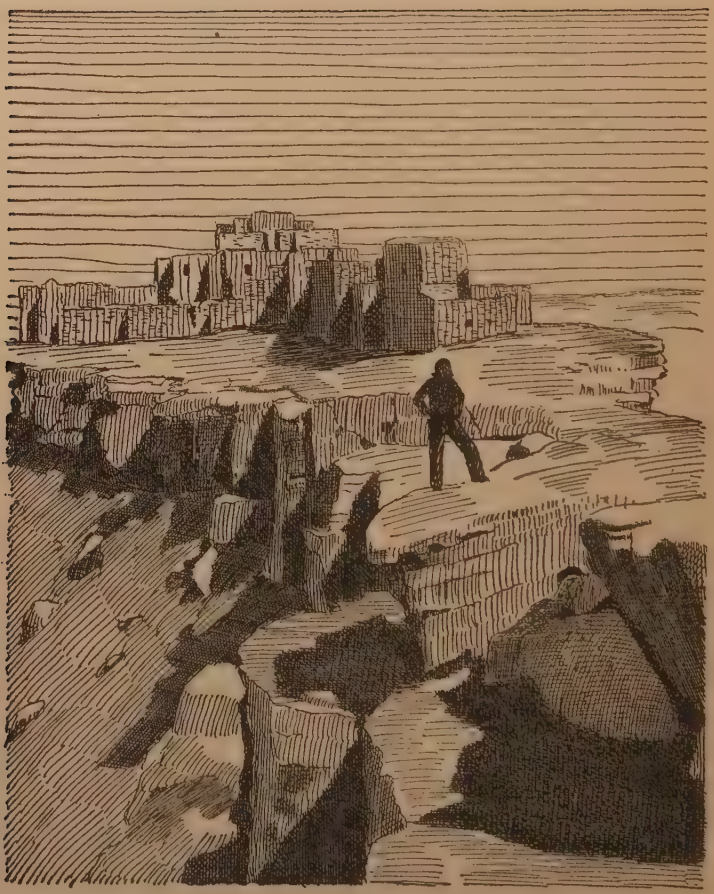


FIGURE 73. *The village of Walpi, Arizona, is typical of the pueblos in the southwest, a few of which are still occupied.*

still living in such villages as Walpi, Arizona. Even in the days of the Spanish Conquest many of the Pueblo towns had been abandoned and were crumbling into ruins or were buried by the sands of that semi-arid region. These were the first American apartment houses, with living quarters closely crowded together,

Figure 74. *When "Balcony House", in what is now the Mesa Verde National Park, Colorado, was first discovered, it appeared as shown in this sketch, drawn from a photograph made by the author in 1910.*

constructed tier on tier to heights of five or six stories.

Closely related to the Pueblo Indians were the cliffdwellers whose picturesque ruins lend interest to Mesa Verde National Park and adjacent portions of Colorado, New Mexico and Arizona. Many of the crumbling stone walls clustered beneath the shelter of overhanging cliffs have in recent years been cleared

of fallen débris and partially restored. Cliff Palace, one of the largest of the communities, now appears as in the accompanying sketch. The great round pits in the foreground are ceremonial rooms, originally roofed with logs and dirt, into which the members

Figure 75. *Cliff Palace, Mesa Verde National Park, Colorado, with its many tiers of rectangular apartments and its circular ceremonial chambers, all walled with sandstone blocks set in adobe cement, was constructed by cliffdwellers between 1073 and 1262* A.D.

of the various secret societies were wont to descend to perform their mystic rites. The square apartments farther back beneath the sandstone roof of the alcove are living quarters; probably five or six hundred Indians resided in this one community when it was at the height of its prosperity. In dark recesses at the very back of the cave are storage bins for maize and

other foods, as well as refuse heaps and junk piles. The articles found in such places reveal the cultural level and workmanship of the former inhabitants, and an occasional dessicated body or buried skeleton indicates their biologic status. All are closely similar to the modern Pueblo Indians in skull shape and facial features. They were apparently a peace-loving folk who built their homes in sheltered alcoves in these inaccessible canyons for protection from their war-like contemporaries.

At first glance, the ruined cliffdwellings have an appearance of great antiquity, but they really take us back only a few hundred years in the history of American civilization. During the last decade a remarkable bit of scientific research has provided a way for ascertaining their precise chronology. Both cliffdwellers and pueblo builders used tree trunks to support the roofs and floors of their many-storied dwellings. Some of the beams are so old that they almost crumble to dust when touched; yet in the dry atmosphere of the plateau country they have not decayed and hence still display their rings of growth. An unusually dry or unusually wet year is indicated in the growth rings of every tree in the southwest that was alive in that particular year. Peculiar sequences of years can be detected; for example, one unusually dry year, followed by three wet years, then two dry years, then five average years and again two wet and two dry. Such a sequence may occur in one log just inside the outer bark during the last few years in the

life of the tree; whereas in another log it is down near the center of the cross-section, early in the life of that tree. By matching together such records of past climatic cycles, it has been possible for Dr. A. E. Douglas, of the University of Arizona, to compile a tree-ring chronology somewhat analogous to the clay-varve chronology of late glacial time, which carries the calendar back from historical days to the birth of the oldest trees which have been preserved undecayed in this region.

The oldest log which Dr. Douglas has found was used in the construction of Pueblo Bonita. It was cut down in the year 919 A.D. and was a little over two hundred years old when cut. The tree-ring chronology is thus complete from the year 700 to date. Cliff Palace was constructed between 1073 and 1262 A.D. Practically all of the pueblos and cliffdwellings of the southwest were built subsequent to 900 A.D., a small fraction of the time since the close of the Great Ice Age.

But some of the cliffdwellings contain no timbers, and among these are crudely built structures which have every appearance of greater age than the large community dwellings with their expert masonry. The inhabitants of some of these crude shelters, such as those in Walnut Canyon, Arizona, did not make pottery as did the typical cliffdwellers, but used only baskets to contain their food and other supplies. They had not yet learned how to bake or burn clay to make earthenware vessels. The transitional

stage between the primitive basket-maker and the expert potter is recorded by the presence of baskets the outside of which is smeared with clay. Doubtless the idea occurred to someone to hasten the process of drying the clay by heating it, instead of merely leaving it in the sun to dry. The fire not only baked the clay, but also burned up the basket; the result was an earthenware vessel—the art of pottery-making was born.

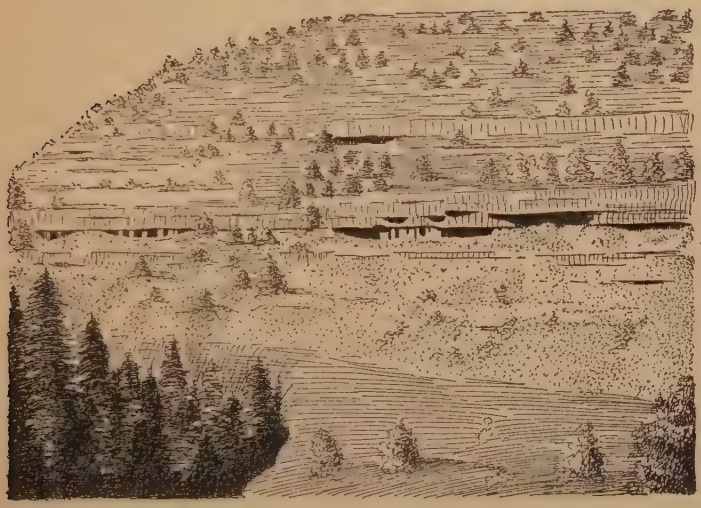


FIGURE 76. *Some of the crude dwellings, constructed beneath rock ledges on the walls of Walnut Canyon, Arizona, were inhabited by the basket-makers before the Indians of the southwest had learned the art of pottery making.*

The greater antiquity of the basket-makers is further indicated by the fact that they possessed only two varieties of maize, whereas the cliffdwellers culti-

vated six or eight distinct varieties. Maize or "Indian corn" was originally a wild plant, found by American aborigines somewhere among the plateaus of Mexico or Central America. Under cultivation many different varieties of corn were produced and these became the mainstay of the cliffdweller's diet as of most of the earlier inhabitants of southwestern America. Undoubtedly it required a considerable interval of time to produce the new varieties of cultivated maize and to develop the fine technique of the potter. There is no way of determining with precision the rate at which the Luther Burbanks and Josiah Wedgwoods among the first families of America accomplished their tasks, but there is no reason for assigning the basket-makers a greater antiquity than a few thousand years. Their culture was doubtless contemporary with that of the Assyrians, Athenians and Romans of the Mediterranean region.

Most remarkable of all the pre-Columbian civilizations which have yet been revealed by the "magic spades" of American archeologists is that of the Mayas of Central America. These peoples, together with the Aztecs, Incas and other inhabitants of Central and South America, built closely settled cities, magnificent temples and strong fortresses. They were superb architects and builders; their stone work was rarely if ever equalled before the "age of power." Their temples, palaces and pyramids are now crumbling ruins, but much of their original beauty has withstood the

hand of time and the spoliation of the European conquerors of their inhabitants.

The Mayas had achieved a written language, but almost all of their documents were long since destroyed. Their barbarous religion with its human sacrifices angered the righteous conquistadores, and the written records of the Central Americans were gathered together and ruthlessly burned during the sixteenth century. Only three documents are known to have escaped annihilation and these are now preserved in the British Museum. They are mere fragments of what must have once been a priceless library of early American history.

Fortunately, the Mayas, like the ancient Assyrians and Egyptians, had the custom of engraving in stone a record of the exploits of their princes and the campaigns of their armies. The stone stairway which leads to the summit of the templed pyramid at Copan on the Peninsula of Yucatan is one of many structures covered with deep-carved hieroglyphics which reveal remarkable attainments of the priests and scholars of this vanished empire. The Maya calendar, like ours, was based upon observations of the sun, moon and stars, and was fully as accurate and precise as that which we use today. But, whereas our Gregorian calendar was not perfected until 1582 A.D., the Maya calendar began to function in 613 B.C. The Maya scholars with their scientific measurements succeeded in computing not only the length of the solar day and

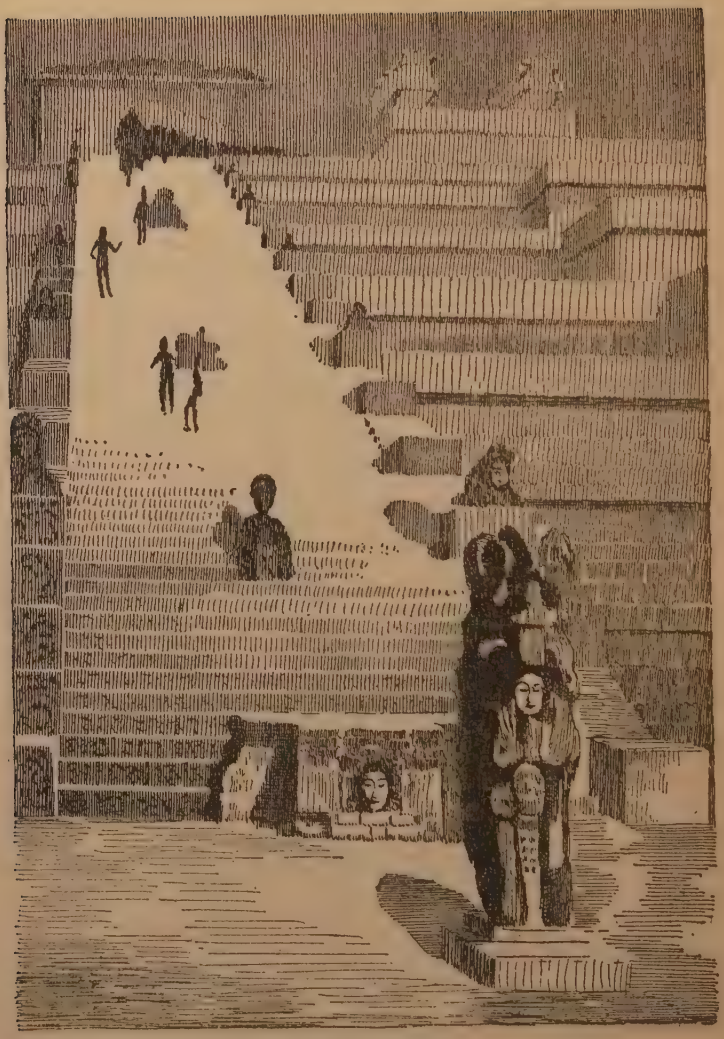


FIGURE 77. *The hieroglyphs on the huge stone stairway at Copan, Honduras, constitute one of the longest Mayan inscriptions known. The stairway is now in ruins, but it is shown here as it appears in an imaginative reconstruction by Dr. G. B. Gordon and Henry Sandham.*

(AFTER DRAWING IN "NATURAL HISTORY," VOL. 28, P. 395, 1928.)

lunar month, but also the time required for the planet Venus to complete its circle about the sun.

Obviously, the Maya race must have inhabited portions of Central America for a long time prior to the establishment of their calendar, but even so there is no reason for assigning to them any truly great antiquity. Like the moundbuilders, cliffdwellers and basket-makers, they are members of the species Homo sapiens, with skeletal features and craftsmanship comparable to those of the Cro-Magnon man of Europe rather than to those of the Neandertal or older types. All these peoples, together with the so-called natives of North and South America encountered by the European discoverers of the New World, display specific characteristics which ally them closely to the Mongolian inhabitants of eastern Asia. All the evidence unites in forcing the conclusion that America is not the birthplace of mankind, but is rather a land into which human beings migrated in comparatively recent years.

No skulls, teeth or jaw bones similar to those left by such prehuman creatures as Eoanthropus, Pithecanthropus, or even Homo neandertalensis have thus far come to light on this side of the Atlantic Ocean. On several occasions, fossils found in North or South America have been enthusiastically announced as representing primitive anthropoids or even extinct species of the human family, but when summoned before the bar of scientific scrutiny such interpretations have invariably proved fallacious. For example, there

is a series of specimens which were once described by Ameghino, a Latin-American paleontologist anxious to prove that South America was the birthplace of mankind. To these specimens, arranged in sequence to suggest the evolution of man from the New World monkeys, a number of new generic and specific names were given. But upon careful examination by those qualified to judge, each of these fossils is now known to have been erroneously interpreted. Ameghino's series of prehuman ancestors from South America never existed except in his own imagination. The less said about it and the sooner it is forgotten the better for all concerned.

The close-knit unity of the existing species of mankind is not a theological dogma; the brotherhood of man is a biologic fact, regardless of its philosophical or spiritual import. It may be true that anatomical differences between various ethnic groups, such as the Negritos and the Nordics, are so great that anthropologists would long since have divided Homo sapiens into several separate species, instead of subdividing the single species into several races, were it not for the theological heritage under which even the most heretical of modern scientists still labors. Nevertheless, the many ethnic strains recognizable among the present members of the human family have come from a common ancestral source—human beings who lived in the later half of the Pleistocene period.

The cradle of the human race must have been situated within two thousand miles of the eastern end

of the Mediterranean Sea, probably in south-central Asia, possibly in northeastern Africa. From this locality, successive waves of migrant humanity have made their way to distant lands. Although in a sense analogous to the movement of spreading ripples on the surface of a placid pool into which a pebble has been thrown, the outward spread of mankind was excessively slow. Hundreds of years and scores of generations were involved in the traverse of a continent. Along the routes which radiated outward, heredity and environment were playing their customary rôles in the drama of evolution. The farther from their common starting point the emigrants are found, the more unlike their common ancestor are they likely to be.

An early exodus carried the Piltdown man to northwestern Europe and the British Isles, at a time when those islands were part of the mainland and the English Channel was a broad valley floor. Another route was followed by an expeditionary force which finally reached what is now the island of Java and left the "ape-man" there. Likewise other leisurely wanderings took Sinanthropus across Asia toward its eastern margin and transported Australopithecus southward into Africa. While these pioneers were journeying farther and farther from their homeland, the evolutionary process was continuing to alter the central stem of the human family tree. In consequence, the later emigrants were as a rule farther advanced than were the earlier. Among them were the Heidelberg

and Neandertal men, and still more recently the Cro-Magnon and associated races.

The spread of modern man to all habitable parts of the globe has been a very complicated process and many of its details are still unknown. But the major facts concerning it are fairly well understood. From the birthplace of Homo sapiens, not far distant from the eastern end of the Mediterranean, four great streams of humanity have made their way. One moved toward the southeast into the Malay Peninsula and thence across the stepping stones provided by the islands of the Malay Archipelago to Australia. It was composed of the various members of the Australoid race, the least progressive of existing subdivisions of mankind. A second stream was directed southwestward into Africa south of the Sahara Desert and populated that region with Negroid types. A third group, the Caucasians, moved westward along both shores of the Mediterranean and northwestward across Europe to disperse the so-called "white race" throughout the area occupied by it prior to the fifteenth century. The fourth "river (which) went out of Eden" made its way eastward and northeastward across Asia and thence from Siberia to Alaska and onward down the full length of the two Americas, distributing the Mongoloid race over that vast area.

In all probability the individuals comprising these several migrant hordes were a motley crew, leaving their ancestral home at various times and in various stages of evolutionary development. Along the

FIGURE 78. *Major currents in the prehistoric spread of the modern type of humankind over habitable portions of the globe from the "cradle of the race" in south central Asia are best represented on a map, drawn as though one were looking down upon the northern hemisphere, with the North Pole at the center and the lands of the southern hemisphere spread out beyond the equator.*

way they responded to the local geographic conditions of climate, topography and natural resources. The farther they went, the more each group was differentiated from the others in color, physiognomy, mental traits and cultural features, until ere long the major divisions of the human family were clearly demarked.

Three possibilities come to mind when one considers the geologic date at which the van of the Mongoloid expedition first reached North America. The invasion might have begun just prior to the spread of the last ice sheets of the Pleistocene Period over the northern part of the continent; it might have occurred during the Wisconsin glacial stage while that ice was at its maximum advance; or it might have been delayed until the glaciers had dwindled nearly or quite to disappearance.

The Iowan-Wisconsin interglacial interval (see the table of Pleistocene events on page 108) was characterized by a climate at least as warm as that of the present day. It was probably during this interval that the lake beds in the Don Valley near Toronto, referred to on page 24, were deposited. These contain fossil remains of the paw-paw and osage-orange, plants which today cannot grow as far north as that locality. No serious climatic barrier would then have retarded human migration around the northern rim of the Pacific basin. It may well be doubted that the Mongoloid migration could have reached the northeastern corner of Asia by so early a date as this suggestion implies, but there is no known fact which

would bar this first of the three possibilities from consideration. Indeed, one must at present be ready to welcome the possible discovery that the first immi-

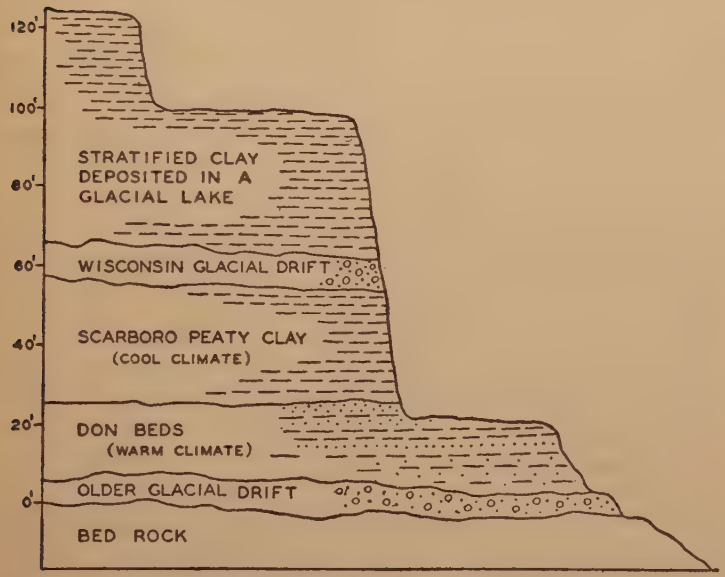


FIGURE 79. *The various layers of sand, clay and glacial débris in the Don Valley, near Toronto, Ontario, contain fossil plants which indicate that in at least one of the interglacial intervals the climate there was somewhat warmer than it is today. This vertical section through the deposit shows the relations of the several formations.* (AFTER A. P. COLEMAN.)

grants to reach America by this route were representatives of a more primitive race or species, who blazed the trail for the later Mongoloid movement.

The second suggestion is far more plausible than at first thought it appears to be. The refrigeration

of the globe implied by the spread of Wisconsin ice southward as far as central Ohio and across all of New England to Long Island must also have chilled appreciably the lands along the northern shore of the Pacific Ocean. But there was no impassable barrier of snow and ice upon those lands. Strange as it may seem, the thousands of square miles of lowland drained by the Yukon River in Alaska remained unglaciated throughout the entire Pleistocene Period. Alaskan glaciers, like those of the Alps, were far more voluminous during the glacial stages of the Great Ice Age than they are today, but they fell far short of covering the northwestern corner of the continent. Nor was Siberia buried beneath a mantle of ice; at their maximum spread the Siberian ice sheets were trivially small when compared with those of Canada and the northern states.

Furthermore, the land bridge between Asia and North America was much more nearly continuous at the climax of the Wisconsin glacial stage than it is today, for sea level was then, on the average, more than two hundred feet lower than it is now. The great volume of water impounded as ice upon the land was in the last analysis withdrawn from the sea. Normally, a definite proportion of all the water which belongs to the earth is temporarily to be found above sea level, in the clouds, falling as rain or snow upon the land, standing in lakes, ponds, snowfields and glaciers, or running back again down the rivers toward the sea. The volume of water in the oceans is

fairly constant because each year just about as much water returns to the sea as is withdrawn therefrom by evaporation. But if the normal sequence of events is interrupted, as it is during a glacial stage, the balance is upset. Imprison millions of cubic miles of water in the form of vast glaciers on the land, and the volume of water in the sea is appreciably lessened. The Alaska Peninsula and the Aleutian Islands, which separate the Pacific Ocean from Bering Sea, are the higher summits of a partially submerged mountain range which rims the north Pacific Basin. When the level of the sea was lowered as it must have been during the Wisconsin glacial stage, that mountain range would have provided a nearly continuous land bridge across which human beings could have made their way dry-shod for the greater part of the journey from Asia through the "back door of the New World." At the same time, the shallowing of Bering Sea and Bering Strait must have caused Siberia and Alaska well-nigh to coalesce, just south of the Arctic Circle, and thus another closely adjacent route was provided.

The third possibility, that the introduction of man to the Americas was delayed until the last of the ice sheets had dwindled nearly or quite to disappearance, must be considered from another angle. This suggestion involves no difficulties with respect to climatic barriers or available routes. Although the stepping stones between Asia and North America must have been fewer and more widely separated after the return to the sea of the melt water from the ice, they

would even so be adequate for the journey. But after the arrival of the Mongoloid van in the western hemisphere and prior to the year 1000 A.D., time enough must have elapsed for the differentiation of the several American cultures which ran the entire gamut from the forest dwellers of the northeastern states, through the moundbuilders of the eastern interior and the cliffdwellers of the southwest, to the Maya confederation in Central America and the Inca Empire in Peru. All had a common ancestry, but each must have been quite distinct from the others for a long period of time. The development of several score of Indian languages and dialects from the one ancestral Mongoloid tongue involved geographic segregation of various groups for many generations. It may be that the scant ten thousand years or thereabouts available since the ice sheets disappeared from Canada is adequate for such cultural differentiation and linguistic development, but there is no certainty that such was the case.

The question of the antiquity of man in America must in the last analysis be answered by the appeal to geology. With what geologic formations are the oldest fossil remains of man or the oldest implements shaped by human hands associated?

No undoubted relic of human life has thus far been found in any deposit in the western hemisphere, overlain directly by glacial drift. Although interglacial beds beneath glacial deposits, such as those in the Don Valley region, are not uncommon in the

northern states and Canada, the only fossils which they have yielded are those of plants and lower animals. These reveal the nature of the animal life which inhabited this continent during various stages of the Pleistocene Period, but they tell nothing concerning man. Negative evidence in paleontology is apt to be untrustworthy, but so far as it goes it indicates that no large number of human beings dwelt in the northern half of North America prior to the Wisconsin glacial stage.

Beyond the area covered by Pleistocene ice there are several known occurrences of human bones or artifacts which deserve careful scrutiny. Among these, one of the most important is in Florida, just the place to which the aborigines would be expected to resort when New England and Michigan were buried beneath the ice of the long glacial winter. It was announced in 1917 that human skeletons had been found near Vero, Florida, in association with the bones of early or middle Pleistocene animals. Many experts immediately visited the locality. It was at once noted that the human skeletons were of a modern type, unmistakably the Mongoloid race of Homo sapiens, and that the artifacts included pottery as well as neolithic implements. If therefore these were truly early or middle Pleistocene in age, it would mean that human culture in North America had reached the Cro-Magnon or an even higher level while only the Piltdown or at most the Neandertal level had been attained in the Old World. Careful study of the occurrence near

Vero led the geologists who examined the locality to the conclusion that the human bones and artifacts had been introduced into the layer of early or middle Pleistocene age long after it had been formed, either by artificial means such as burial in graves, or naturally by streams which cut channels in the older deposits and filled them with more recent sediment and débris. There were, however, a few of the experts who in 1917 and 1918 believed that the entire deposit had been made at one time and that the human remains were contemporaneous with the bones of extinct animals scattered widely through the formation.

As usual in such scientific arguments, the only satisfactory way to settle the dispute is to discover additional facts. In the case of the Vero artifacts and fossils that has recently been done. Under the direction of Professor Loomis of Amherst College a rather extensive program of research was completed in 1925. Human bones or tools were found that summer at four localities near Melbourne and Vero. Throughout this part of Florida are many ancient river channels which were filled with sand, gravel and river-borne débris during Pleistocene time. Spread over these river-laid sands are other layers of white sand alternating with layers of black vegetable matter. Professor Loomis found that all of the animals, such as the species of horse, camel and tapir, which are characteristic of the earlier part of the ice age in America, were confined to the lower of these two types of deposits, whereas all the relics of human activity were

in the overlying formation or at its base. Here the artifacts and human bones were associated with the bones and teeth of mastodons and mammoths, but not with the fossils of early Pleistocene age. It may now be asserted quite definitely that human beings were present in Florida before the mammoth and the mastodon had disappeared from that region. These creatures are supposed to have become extinct in North America long before white men reached that continent, but their remains are frequently found in peat bogs and swamp muck on top of the Wisconsin glacial drift. Therefore the association of human relics with their bones indicates an antiquity for man in Florida of less than ten or twenty thousand years.

Other important data have been obtained in the last five years by scientists of the Colorado Museum of Natural History, working in coöperation with experts from the American Museum of Natural History at several localities in the Great Plains. Unquestioned artifacts, notably different from the flint implements of the North American Indians and resembling closely in workmanship the Solutrean implements of central France, have been found in association with the fossilized bones of extinct bison near the small town of Colorado in Mitchell County, Texas, and near the town of Folsom, Union County, New Mexico. At each of these localities the flint weapons were so related to the bison bones as to indicate that they had been contributory causes to the animal's death. The Folsom type of arrow point or

javelin head is known only from a comparatively small region, embracing parts of Colorado, New Mexico and Texas. It has been found under geological conditions which indicate an age of several thousand years, but it has not yet been possible to date the Folsom culture with any high degree of precision.

FIGURE 80. *The flint weapons used by the bison hunters who lived long ago near Folsom, New Mexico, are strangely reminiscent of Solutrean artifacts. Two of the recently discovered relics of Folsom culture are shown here, with a side as well as front view of each.*

(DRAWN FROM PHOTOGRAPHS SUPPLIED BY HAROLD J. COOK.)

It is certainly much older than that of the basket-maker, but its time relations to the Wisconsin glaciation are not ascertainable. The men who chipped the Folsom implements lived before the flat-horned bison and the ground sloth became extinct, but that indicates a necessary antiquity of only a few thousand years.

Another locality near Frederick, Oklahoma, has

recently yielded clear-cut evidence of somewhat greater antiquity for man in America. Almost a mile north of that town there is a large gravel and sand pit situated on the top of a long undulating ridge, a hundred feet or more above the surrounding country. The gravel and much of the sand was deposited by a tributary to the Red River when what is now the ridge crest was a part of the stream bed. Since then the yielding rocks on either side of the gravel-strewn channel have been eroded away and the present topography has been developed. This must have required tens of thousands of years, but there is no way of measuring the rate of erosion to ascertain how many tens of thousands were involved.

In the lower gravel layers of the Frederick locality, there are bones of rather primitive elephants, a ground sloth, three species of horse and two of camel. All these creatures are believed to have become extinct in North America before the end of the Pleistocene Period. Firmly cemented in the gravel bed with the bones was found a single flint arrow or javelin point. It is rather crudely fashioned and is to be compared with paleolithic rather than neolithic implements from Europe. Somewhat higher in the stratified sand and gravel, other artifacts have been discovered. These are well above the layers carrying the fossil bones of extinct mammals, but are overlain by other layers of sand containing rather abundant remains of the more advanced type of mammoth, the "Columbian Elephant."

Summarizing the information now available, it may be stated definitely that man reached North America prior to the extinction of several species of mammal which were abundant here during the Great Ice Age. The camel, horse, flat-horned bison and primitive elephant are not known to have lived on this continent past the climax of the Wisconsin glacial stage, but there is a possibility that they did so. The mammoth, mastodon and ground sloth are known to have persisted long after the ice sheets of that stage began to wane and may not have passed out of existence until a few hundred years ago. The elephant-head motif appears frequently in the Maya sculpture, and there is a record of a Maya feast about the year 400 A.D. at which mastodon meat was served. Professor W. B. Scott of Princeton University believes it very likely that Columbus might have seen living mammoths had he been able to visit the right localities. The association of human fossils and artifacts with the bones of so many animals which no longer live on this continent nevertheless suggests an antiquity of many thousands of years. Not all of these creatures could have lived in abundance and then abruptly disappeared five hundred or a thousand years ago. Surveying all the data, it would appear most likely that man crossed from Asia to North America at or very shortly after the climax of the Wisconsin glacial stage and spread over the available lands while the ice sheets were melting away. If this is correct,

the first families of America reached this continent thirty or forty thousand years ago, and Homo sapiens has dwelt in America nearly or quite as long as he has lived in western Europe.

Chapter 7

The Heritage from Mother Earth

"I dream no dreams of a nurse-maid state
That will spoon me out my food.
A stout heart sings in the fray with fate,
And the shock and sweat are good."

BADGER CLARK IN THE WESTERNER

In any attempt to explain rather than merely to interpret a set of facts or a series of events, there is involved the correlation of cause and effect, a correlation which necessarily leads into the field of speculation where personal opinion bulks large. This is the case chiefly because of the difficulty of determining with absolute certainty the real cause of many events which have been observed or of conditions which have been noted. The fact that one event often or perhaps always follows another in time does not necessarily mean that the earlier is the cause of the later. When therefore we scrutinize man's heritage from Mother Earth with the hope of discovering the basic causes of human prosperity, we must leave the firm ground

of ascertained facts and venture into the treacherous territory of conjecture. Fortunately, our speculations will be hampered by facts which confine them within narrow limits, yet many of our conclusions must remain perhaps forever in the realm of opinion rather than of demonstration, of belief rather than of knowledge.

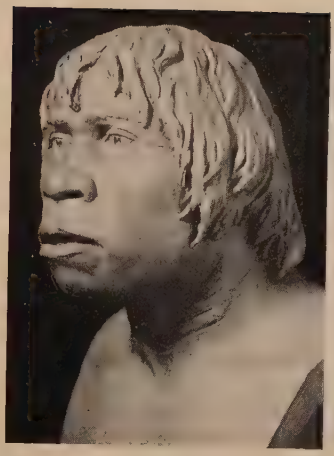
The record thus far made known in the study of Mother Earth's diary makes evident that during the evolution of life upon this planet there has been a most remarkable progress from simple to complex creatures, from lowly to more highly organized animals and plants. It is not merely that in successive periods of time creatures more and more closely approximating man in body form and organic function have made their appearance upon the pages of geologic history. Progress may be observed wholly impartially by noting the number of ways in which the individuals at various levels of evolutionary development are able to respond to the external stimuli provided by their environment, or by the number of different conditions under which they may continue to exist. Without considering which is inherently "better"—an earthworm's burrow, a beaver's house, or a bond-salesman's home in the suburbs—we may simply enquire how many different kinds of structures can each of these species of builders construct. In how many different ways can each express its own individuality? In how many different environments may each live? On that basis alone, there has been

progressive improvement in the ability and proficiency of Mother Earth's offspring from geologic age to age. Certain creatures are "higher" than others not because they are more man-like, but because they are more capable when measured by this entirely impartial standard.

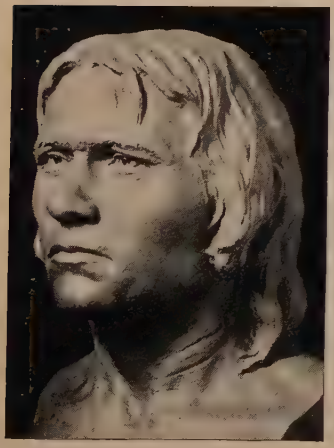
In the evolution of life from lowly creatures to higher forms, and especially in the strain that leads to man, increasing emphasis has been placed upon psychological characteristics. The development of mentality as an important directing force, a dominant factor in the never-ending process of creation, culminates at the present moment in the social and personal life of the existing species of humankind. Why there should have been any progress at all, and why evolution should have followed such a course, are questions repeatedly asked but not yet finally answered. The geologist believes that reasons for the success of human stock, the explanation of man's present prosperity and the hope for his future improvement are all to be found in the total environment provided by the earth on which we dwell.

PLATE VII: *The four photographs forming this plate are models of prehistoric hominoids, prepared by Professor J. H. McGregor of Columbia University and the American Museum of Natural History.* A *is a restoration of Pithecanthropus erectus, based on the fossil bones found at Trinil, Java, in 1891 and 1892.* B *is a restoration of Eoanthropus dawsoni, based on the skull and jaw found in 1912 at Piltdown, Sussex, England. The skull found at La Chapelle-aux-Saints, Carreze, France, in 1908 was used as the basis for the restoration of Homo neandertalensis shown in photograph* C. *The Cro-Magnon man, photograph* D, *was modelled from a skull found at Les Eyzies, Dordogne, France, in 1868.*

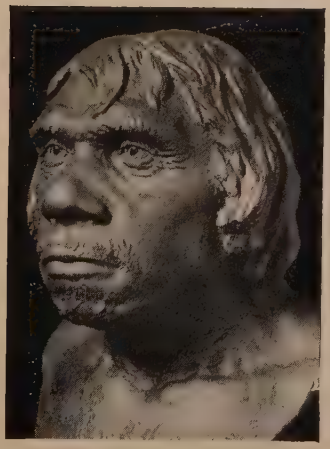
A



B



C



D

Prosperity and success, like everything else in this age of relativity, are purely relative terms. Long-continued, agreeable existence seems to many to be a most successful accomplishment, but from the point of view of the evolutionist, such an aim is certainly not the most desirable. If this be the measure of success, then to creatures other than man must be awarded the palm of victory. The waves which beat today upon the rocky headlands along the coast of Wales are exhuming fossils from Cambrian rocks formed a half billion years ago. Among those fossils are the petrified shells of certain brachiopods, which when they fall into the water along that shore are mingled with the shells of living brachiopods, from which they are scarcely distinguishable in so far as their biologic structure is concerned. Throughout all geologic history from the beginning of the Paleozoic Era to the present time, that type of brachiopod has maintained its existence, with little change, upon its own particular level of activity. Those shell-fish have four hundred and ninety-nine million, nine hundred and fifty thousand years' start on us in the race for longevity!

To the evolutionist, success means not continuity of existence, but rather perfection of the body structure, increase in the complexity of organs, nerve system and muscular arrangement, gain in ability to enter new areas for conquest, acquisition of new modes of self-expression, enlargement of the interest of the individual in its surroundings, expansion of

the horizon of one's life. What has caused that sort of progress, especially in the strain that leads to man?

Evolution has not been thus progressive for all creatures. Progress is apparently selective; many may be called, but certainly only a few are chosen. At each forward step in life development, it has always been a minority, numerically trivial, which has gained the new level of achievement. At no time has the process of evolution guaranteed success to any species, if success be measured in terms of progress or improvement. It has simply guaranteed change—a change which has sometimes been for better, but has often been for worse.

And the species which have changed for the better have thereby passed out of existence! It may almost be said that the most successful species have been the shortest lived. To pass on the torch of life to a higher level, the torch-bearer must become extinct. The old species dies, that the new species may be born. As soon as changes in the organism are sufficiently conspicuous to be noted by the critical student, he gives a new specific name to the modified offspring and announces that the old species has passed away. In biologic evolution as in certain other fields of activity, he who would save his life must lose it.

A review of certain achievements which have been accomplished along the path of life and an attempt to relate them to their contemporary geologic environment will give at least a suggestion as to why

evolution has on occasion been progressive. From such suggestions may be learned much of value concerning the real basis of human prosperity, the true nature of the heritage from Mother Earth.

There is no record of the first important change which must have taken place among living creatures on the earth. It occurred long before any opportunity was provided for its registration on the pages of geologic history. But its nature may be inferred from events which were later chronicled. The initial living being, the first creature to live upon the earth, must have been at least as lowly and simple as the lowliest and simplest form of life existing now, or as the single cell with which each animal and plant starts its individual existence. The primordial one-celled organism must have possessed the characteristics of both plants and animals, or potentialities which in succeeding generations developed into the characteristics of the animal kingdom on the one hand and the plant kingdom on the other. Apparently very early in the history of that first creature and its immediate offspring, a fork appeared in the path of life. Some individuals took the road to the left, others bore to the right; the distinction between the plant and animal kingdoms was thereby established. Plants, other than parasitical forms, possess a green substance known as chlorophyl, which enables them to utilize directly the energy of the sunlight and to manufacture food for themselves from carbon dioxide in the air and mineral matter in the ground. Animals have no such abil-

ity; they must subsist upon food already manufactured for them, either by other animals or by plants. The classic jingle

> *"The little fleas that us do tease*
> *Have other fleas that bite 'em;*
> *And these small fleas have smaller fleas*
> *And so ad infinitum."*

is not strictly true. Long before "infinitum" is reached in the chain of animal interdependence, the complete dependence of the entire animal kingdom upon plants is profoundly apparent. In a very real sense, all animals are parasites upon the face of the earth. If the plant kingdom were destroyed, animal life would necessarily pass out of existence very shortly thereafter.

This significant difference in the relations between the two great kingdoms of living creatures and their food supplies was established long before the oldest known fossils were formed. Some of the offspring of the primordial unicellular plant-animals were devoid of chlorophyl. Because of that deficiency they were forced to devise ways and means of securing food. Their kindred possessing chlorophyl could get food anywhere at any time; it was brought to them by the restless breeze and the water circulating in the ground. They need only find for themselves a place in the sun and remain there serene and content. But without chlorophyl the ancestral animals must develop organs of locomotion to convey them

to the food already manufactured by the plants; they must develop organs of sense to enable them to recognize the presence of food in their immediate environment; they must devise machinery for the coördination of their various activities so that the search for food may be intelligent and efficient. All such organic structures are a direct consequence of the loss of chlorophyl. Perhaps this is an illustration of one of the fundamental laws of life: loss, handicap and sacrifice lead to gain, advance and improvement.

However that may be, an early consequence of this first significant change among living organisms was the necessity of active rather than merely passive adaptation of each creature to its particular environment. Certain organic structures were found to be more suitable for certain environments, and the separation of various types of animals on the basis of their preference for peculiar surroundings naturally followed. This segregation gave opportunity for the fixation of habits and the perpetuation of specific and generic characteristics. Immediately, the changing physical conditions of the earth's surface became an important directing factor in the process of evolution.

The changes which took place among the invertebrates which inhabited the seas in early Paleozoic time are of special importance because among those creatures were certain individuals which were developing toward a stage not previously known, from which could arise the primitive fishes, ancestors of all higher vertebrates. Marine invertebrates, then as

now, were concentrated in the shallow seas along the margins of the continents or in great embayments which like Hudson Bay had spread far toward their interior.

The Paleozoic oceans were subject to marked fluctuations in area. At least once, and more commonly several times in each period, the marginal seas advanced upon the land, flooding with comparatively shallow water the broad lowlands of the continental interior. The Gulf of St. Lawrence expanded southwestward into what is now Pennsylvania and Ohio; the Gulf of Mexico spread northward into Kentucky and Illinois; embayments of the Pacific Ocean encroached upon the western states and repeatedly submerged the area now occupied by the Rocky Mountains; the waters of the Arctic advanced southward even as far as Iowa and Minnesota. Each episode of continental flooding was followed by an interval of sea withdrawal during which the area of dry land expanded to dimensions similar to those of the present day.

These oscillations of level of land and sea altered the total area of the oceans by proportionately small amounts, but they occasioned great relative changes in the area of the shallow seas. At times of marine expansion the area of water less than 100 fathoms (600 feet) in depth was often ten times as great as that during the succeeding episode of sea withdrawal. This must have worked a veritable revolution among the myriad invertebrate creatures con-

fined to that distinctive habitat; and it was among this particular group that the Paleozoic Era witnessed not simply the greatest variety of new species but also the most noteworthy progress in body structure and individual efficiency. When the shallow seas were transgressing the continental lowlands, the area available for marine invertebrates was increasing; food supplies were abundant; competition was not severe. Each type of life deployed with utter abandon; every possible experiment was tried; new varieties and species appeared, almost without number. In these times of luxury and ease, "expansional evolution" was the rule. Then came a change, as all things earthly change. As the cycle of physical events moved inexorably onward, the seas which had flooded the interiors of the continents began to recede. When an embayment was withdrawn, the creatures inhabiting it were banished to such harbors of refuge as the present Gulf of St. Lawrence or Chesapeake Bay, or to the narrow "shelf seas" which bordered the continents. In these greatly diminished areas, they were crowded into close proximity one with another; food supplies were less sufficient; competition was more severe. As the struggle for existence became acute, the many experiments which had been essayed under the easy conditions provided earlier by the expanding seas were appraised and tested. Not only were the decidedly unfit creatures blotted out of existence, but in very truth only the fittest survived. The minority which met victoriously the tests provided in

these times of "restrictional evolution" passed on the torch of life to the generations comprising the next stage of expansional development. At least thirty cycles of advancing and retreating strand lines occasioned as many pulsations of life during Paleozoic time. Mother Earth was providing an opportunity for the "ceaseless urge" within the organism to experiment with all possible methods of achieving success and then was selecting from the results those which when weighed in the balance, one against the other, proved most satisfactory.

Another geologic factor worked in close harmony with the changing area of the shallow sea. Advancing seas invaded each continent from several points of the compass at the same time. For long intervals each embayment was more or less completely isolated from the others. Today the inhabitants of Hudson Bay are different from those of the Gulf of St. Lawrence, which in turn differ conspicuously from the creatures dwelling in Chesapeake Bay or the Gulf of California. In the main, the Paleozoic seas were probably fairly uniform in temperature, but differed materially in salinity and turbidity. A particular embayment, therefore, might be hospitable to certain species such as are found among the molluscs, but at the same time inhospitable to other animals like the corals or the crinoids. Isthmian or other barriers from time to time effectively prevented the invasion of an embayment by many forms of life inherently suited to its conditions, and thus iso-

lated its local population from foreign immigration. For these and other reasons, provincial faunas characterized many Paleozoic epochs. Each province had its own assemblage of plants and animals, set in a physical environment more or less peculiar to itself. In the attempt to cope with its own special problems, each type of creature perfected its own adaptations to its surroundings. Equilibrium within the province must constantly be maintained, and only those creatures favorably adapted to the local situation could flourish.

But the continued transgression of the sea upon the land at many times resulted in the coalescence of hitherto isolated seas. An embayment from the Mackenzie Valley, extending southward across Iowa into Illinois, might become confluent with an embayment from the Gulf of Mexico, extending northward across Mississippi and Tennessee and reaching likewise into Illinois. As a rule, at the climax of sea transgression there was much commingling of the waters of previously separated gulfs and bays. The result is obvious. Provincial faunas mingled with each other and invaded territories from which they had earlier been barred. Life quickly assumed a cosmopolitan aspect as the old barriers were broken down. Again there was abundant opportunity for appraisals of results thus far achieved. Experiments which had proved successful in one embayment were now compared with the best that had been accomplished in another province. The creatures selected in the re-

gional elimination trials were now pitted against each other in the world championship meet. The cosmopolitan assemblage would be characterized by the best possible selections from the many provincial units.

This shift in emphasis from provincial to cosmopolitan faunas must frequently have coincided with the climax of a phase of expansional evolution. Then as the cycle continued, and restrictional evolution became dominant, cosmopolitanism would be replaced by provincialism. Such episodes succeeded one another with monotonous regularity of sequence, but fresh diversity of results. In these pulsations of the shallow seas is found an effective mechanism which made the evolution of marine invertebrates truly progressive rather than simply variable from one period to another.

The case is particularly clear for animals of that type in the Paleozoic seas, but it is apparent that similar geologic factors have contributed toward the progress of many other organisms at all times. In general, the development of land animals will proceed in a similar cycle but in opposite direction at any one time. Thus, the present conditions of the northern hemisphere of the earth, with its widespread lands and disconnected seas, favor expansional evolution of land animals toward a cosmopolitan type, but impose upon marine creatures the tendency toward restrictional evolution and provincialism. Just the opposite is the situation in the southern hemisphere, where of late the inhabitants of the sea, espe-

cially in the vicinity of Australia, have been enjoying the expansional phase in the cycle of evolution and the land animals have been condemned to most rigid provincialism.

The record of the rocks, which permits us to review the pageant of life as it progresses upon the changing stage of the earth's surface, indicates that many of the most significant achievements in the past were responses to particular environmental conditions. Among these, the emergence of air-breathing quadrupeds from the aquatic surroundings in the midst of which live the gill-breathing and finned fishes constitutes one of the most dramatic events along the road leading toward man. Apparently that event occurred shortly after the middle of the Paleozoic Era, for in the later Paleozoic rocks are abundant footprints and frequent skeletons which indicate the presence of amphibians and reptiles. During the Devonian Period the stage seems to have been peculiarly set for the development of land vertebrates from so-called "lung fishes." The locality in which that important episode occurred was probably either in northeastern North America or northwestern Europe. Conditions of climate and geography in both of those localities at that time are known. The Catskill formation, so named because it forms much of the Catskill Mountains in central New York, is the American prototype of the Old Red sandstone of the British Isles. The two formations are of about the same age and were formed under somewhat similar

conditions. Their physical characteristics indicate a climate marked by pronounced seasonal fluctuations in rainfall. During the rainy season, rivers flooded their banks; shallow lakes and broad swamps expanded upon the lowlands. In the subsequent dry season, the rivers dwindled to a succession of stagnant pools and the lakes became wide salt-crusted expanses of dried mud. That seasonal fluctuation must have imposed upon the inhabitants of those waters a stimulus well adapted to serve as the spur to drive vertebrates from the aquatic habitat out upon the land. Stranded on the expanded river flats as the flood waters subsided, or floundering on the mud floors of dwindling lakes, the lung fishes had every incentive for perfecting the accessory breathing organ which eventually became the vertebrate lung. Mother Nature was verily applying a lash to drive her offspring into a new field of activity.

This of course was not the first time that climatic fluctuation between a wet and a dry season had occurred, nor was it the last time. Many tropical lands display similar changes today, but as far as we know, it was the only time when this important forward step in life development was accomplished. Apparently the environmental change was not effective until the right sort of animal was available to give the necessary reaction to the external stimulus. Not until the Devonian Period were there any fishes possessing an internal structure and a body form which made possible the modification of the swimming bladder

into a breathing lung. Nor is it likely that the air-breathing fishes of the Devonian Period would have given rise to the land animals had not the external stimulus been provided by the peculiar climate and geography of that time. Furthermore, it is doubtful whether the stimulus would have been similarly effective at a very much later date in the history of those fishes. The existing lung fishes show no inclination whatsoever to become air-breathing, lung-possessing quadrupeds. Their ancestors were among the many which had the opportunity, but they were not in the group which responded. They themselves are now firmly established in their own particular niche and show little variation from generation to generation. They have lost the plasticity which characterized their Devonian forebears and have become so fixed in their habits that one must conclude the day of experimentation is long since past for them. The progressive step was, however, taken when the right sort of vigorous organism in a youthful stage of plasticity, such as characterized the lung fishes in Devonian time, was set in the midst of a stimulating and directing environment.

The necessities imposed upon the organism because of certain peculiarities in the environment formed a problem which was not impossible of solution. The upward step involved in the evolution of amphibians from fishes was occasioned by local and temporary geologic factors. No ultimate goal could possibly have been envisioned even fleetingly by am-

bitious fishes. To be sure, the achievement of successful air-breathing apparatus permitted later generations of vertebrates to progress far by numerous subsequent steps, but the future possibilities were not in the least involved in the momentary crisis. Creatures possessing inherent qualifications which made possible the development of primitive lungs were for the moment set in an environment which stimulated that achievement. The result was of far-reaching consequence to all life, and most especially to man.

The outstanding biologic event of the closing Paleozoic periods was the improvement of terrestrial vertebrates until the reptilian stage was reached. The fossil record shows almost completely the transition between certain amphibians and the more lowly reptilian orders. In its simplest statement, this forward step in life development involved two changes, both of which were necessary to liberate land animals from the necessity of retaining close contact with their ancestral aquatic environment. In the first place, the individual's metamorphosis from the gill-breathing to the lung-breathing condition must take place sufficiently early in its life history to be complete before the moment of birth; otherwise, the young must be hatched in the water. In the second place, the egg must be so constructed as to permit its incubation in the air rather than in the water.

Professor Lull has interpreted these changes as a response to a climate becoming progressively more arid. He suggests "that whereas semi-aridity with sea-

sonally recurring rains impelled amphibian evolution, true aridity with undependable rains making amphibian economy impossible stimulated the evolution of the reptiles." This explanation is in perfect harmony with known facts concerning the extension of wide desert areas in what are now the southwestern states, at a time which was approximately contemporaneous with the first records of true reptiles. It happens that some of the very oldest reptilian fossils are found in the Coal Measures of Illinois, in strata whose composition clearly indicates the presence of marshes and swamps of such vast dimensions as to have been possible only in a humid region. These were, however, contemporaneous with vast arid deserts at no remote distance toward the south and west, and it might well be expected that the early reptiles soon sent expeditionary forces from their birthplace in the desert to the adjacent humid lands with their greater wealth of food resources.

A very thorough study of the environment of North American vertebrates in the late Paleozoic was made a few years ago by Professor Case. He concludes from the available data that development of vertebrate life at that time "emphasizes the changes from a long period of slow evolution in a singularly monotonous environment through a period of rapid expansion in a diversified environment" resulting in the final extinction of most of the life strains involved. "The chief directing influence in the sudden expansion was a decided climatic change, accompa-

nied by physiographic changes, induced by an alteration in the level of the surface of the continent." During early Pennsylvanian time, the geologic factors surrounding North American life were unusually uniform over most of the land surface. Apparently there was an equably humid climate; great areas of the continent were very close to sea level, so that wide marshes and swamps were an almost constant feature of the landscape. The ultimate food supply, vegetation, was abundant, and large numbers of animals must have found easy subsistence. The air-breathing vertebrates were still in the first stage of their development—the stage of youth, with all its resiliency, flexibility, and readiness to experiment. But amphibian development seems to have been especially slow. Perhaps the monotony of the environment restricted the progress which might otherwise have been expected. The vertebrate strain was, however, "accumulating force toward a great radiation to be expressed as soon as the limitations were removed even in a partial degree." This was apparently one of several long periods of stagnation in evolution, which were followed by rapid development, a sequence so frequently noted that Professor Case records his "impression that faunas in periods of stagnation go through a period of preparation in some form for their subsequent radiation."

Toward the end of the Pennsylvanian Period, far-reaching physical changes began to make themselves apparent throughout North America. In general,

FIGURE 81. *The strange "fin-back lizard" of the late Paleozoic was one of many responses made by the youthful reptiles to the varied environments of that time. No one has yet given a satisfactory explanation of the "fin" possessed by this inhabitant of desert lands.*
(SKETCH FROM A MODEL BY CHARLES W. GILMORE.)

there was a gradual elevation of the land, accompanied by changes to a cooler and less humid climate. Swamps and marshes dwindled to disappearance; wide sandy wastes extended over large areas in both the eastern and western half of the continent. "The fauna, long restrained from any expression of its evolutionary tendencies, full-fed and in the vigor of its youth, responded at once to the change, and new forms appeared so suddenly as to be unheralded in the preserved remains." Reptiles made their appearance in considerable force and promptly took command of the available lands. Their deployment into diverse strains was unusually rapid and was no doubt a response to the varied opportunities of the notably diversified environment. The strange and mysterious fin-backed lizards, the graceful, slender, swift-moving Areosceles, and the efficiently aquatic mesosaurs represent but three of the many lines of evolution which were pursued.

Somewhat similar climatic and topographic conditions obtained in South Africa at that same period in earth history. There, also, the reptiles took advantage of congenial surroundings and new opportunities. Progress was along very similar lines; but in that locality, one reptile strain showed tendencies which foreshadow the characteristics of mammals. So far as the fossils are concerned, these are most apparent in the teeth and skulls. We know nothing definite concerning progress toward the two truly mammalian characteristics: the utilization of a portion of

FIGURE 82. *This gracefully agile reptile, known as Areosceles, represents one of the many diverging lines into which the reptiles deployed before the close of the Paleozoic Era.*
(AFTER A RESTORATION BY WILLISTON, IN "WATER REPTILES OF PAST AND PRESENT.")

the energy derived from food to keep the body temperature above that of the surrounding air, and the development of mammary glands for suckling the young. It is, however, within the bounds of possibility that both of these characteristics were anticipated among the mammal-like reptiles at that time.

The progressive diversification of climate during late Paleozoic time reached its climax with the arrival of a great ice age—the Permo-Carboniferous glacial period. At that time, three hundred million years ago, just as more recently in the Pleistocene Period, there were repeated refrigerations of climate. Ice sheets invaded the margins of the tropical zone in Africa, South America and possibly elsewhere, at the very time when mammal-like characters made their appearance among certain of the reptiles. Shortly thereafter the first creatures ordinarily interpreted as true mammals left their scanty records in the rocks. Presumably, the distinctive mammalian characteristics were developed in response to the increasing cold of the South African locality in which the "therapsid reptiles" were dwelling.

Obviously, diversification of climate—aridity here, glaciation there—are recurrent episodes in the later history of the earth. The stimulation which such climatic factors give for progressive development among land creatures has been offered many times, but only at one critical stage in the evolution of life were there amphibians capable of responding to the growing aridity and thus of developing into reptiles.

FIGURE 83. *Promptly after the reptiles had succeeded in adapting themselves completely to a terrestrial environment, attempts were made by some of them to extend their domain to include the water, whence their ancestors had come. Web-footed Mesosaurus seems to have found a place for itself in the rivers and lakes of late Paleozoic time.*

(AFTER A RESTORATION BY WILLISTON, IN "WATER REPTILES OF PAST AND PRESENT.")

Only in one epoch were there primitive reptiles, buoyantly youthful, vigorously plastic, and capable of responding to the adversity of progressive refrigeration by developing a mechanism for the manufacture and storage of heat within their bodies.

Among the achievements which distinguish mankind from the other mammals, none is of greater biologic significance than the perfecting of the hind limbs for bipedal locomotion and the attainment of upright posture. These anatomical modifications were accomplished when our prehuman ancestors descended from the trees, among whose branches they had been living, to make their abode upon the ground. This important change occurred in or very near the Miocene Period. Though the conclusion is not at present definitely verified, the probabilities, suggested by all the converging data that are available, point to the south-central portion of Asia as the locality.

The deduction that until mid-Tertiary time man's ancestors had been living in trees is supported by well-nigh incontrovertible evidence. The detailed study of the human skeleton and bodily characteristics, in comparison with similar structures among the apes, indicates that at an early stage in the development of the hominoid strain among the primates our ancestors travelled through the tree-tops, swinging by their fore limbs from branch to branch. Considering the change from an arboreal to a terrestrial abode, the geologist would not look for its explanation in any innate urge within the animal; rather he would ex-

pect to find something in the environment which provided the stimulus for embarking upon what must indeed have appeared to be a most foolhardy and precarious mode of existence, that of dwelling upon the ground. Creatures which have long been safe in the tree-tops would naturally look with amazement upon the suggestion that they descend to the ground and compete there with tigers and other predacious beasts who can run faster than they. In the tree-tops they are comparatively safe; down on the ground they are taking all sorts of chances. Therefore it would seem that there must have been something which actually drove our prehuman ancestors to make the venture and run the risks inherent in the new abode.

On examination, we find that a geologic change in south-central Asia occurred contemporaneously with the change in the habits of mankind. It was in the Miocene Period that the Himalaya Mountains began to be elevated. For long intervals of time, tremendous crustal forces were applied, crumpling that portion of the earth's crust and rearing the great mountain barrier to loftier heights. As the mountains were uplifted, the moisture-laden winds from the southwest were cut off from central Asia. What had been a region of humid, forest-covered lowlands was progressively changed into a series of elevated treeless steppes or open plains. The escape of arboreal anthropoids from that region toward the south into other forested areas was largely cut off by the mountain barrier. Doubtless there were many conservatives

among the inhabitants of those trees who refused to admit that times were changing, who must have looked with surprised disapproval upon the young radicals who insisted that safety lay upon the ground and that they must descend from the trees and begin to adapt themselves to the new condition. Fortunately there were enough individuals who were willing to make the venture into the new and hitherto untried mode of life. Old Mother Earth was selecting then and there not only the hardiest but also the most courageous and enterprising of the group. It is to them that we may proudly trace our family lineage.

The record in the rocks indicates nothing inherent in primitive one-celled animals which made necessary their evolution from that early stage through successive generations of offspring until finally they became men and monkeys, horses and dogs, elephants and whales. These changes did take place, but there is no evidence of any impulse within the creatures which necessarily drove them forward. Each creature aimed, not for a far-off goal, but for the immediate one of self-preservation. As various types of animal and plant life succeeded thus in adjusting themselves satisfactorily to the conditions of time and place, they frequently lost the ability to make any further modifications. They dug so deep a groove for themselves in the highway of life that it was impossible for them to escape into new paths when the geographic environment changed around them. Those are the derelicts of the past; the genera, families or even orders

of animals and plants which, reaching the end of a blind alley, were forced into extinction. But fortunately at each stage in earth history there were organic strains here and there which were capable of modification under the compelling spur of new conditions. As a rule, these tried all possible experiments. As John Burroughs put it, "Nature hits the mark because she shoots in all directions." But that is only half the story. There must be something which singles out the most desirable mark to hit, which draws the specifications for the target. Environmental changes seem to be the selective agency which determines the course of evolution.

In this connection, the history of life upon the earth sheds considerable light upon a possible theory regarding the presence of living creatures on other planets. The announcement of the discovery of a ninth planet beyond the orbit of Neptune provokes anew the enquiry concerning existence on other worlds than ours. The psychology of "the man from Mars" has been largely discussed, and the question concerning the presence on that neighboring planet of more or less intelligent, man-like creatures has been debated. If the successive stages in the geologic history of the earth have determined the course of evolution here, then to produce a man-like being on Mars would require the precise reproduction there of the geologic history of the earth. The structure, mass, composition, and external relations of Mars are all sufficiently different from those characteristic of the

earth to make it absolutely certain that the surface of Mars has not gone through a sequence of geographic and climatic changes comparable to those which have occurred upon the earth; nor could similar changes have happened in the same order on the two planets. Impressed as we must be by the importance of the unique succession of felicitous events, dependent upon the internal conditions and external relations of the earth, which have been responsible for the peculiar direction taken by organic evolution, we cannot escape the conclusion that to duplicate the evolution of man, the earth and its geologic history must be precisely duplicated. It is hardly to be expected that another planet, even among the many planets which may pertain to the stellar galaxy, could have had a geologic history sufficiently similar to that of our earth to have developed life along similar channels. Although there is no apparent reason for assuming that life, as we know it, represents the only possible manifestation of the mysterious vital forces inherent in the universe, this is a strong argument in favor of the view that man is actually unique in time and space. The law of probabilities practically excludes the thought that anywhere else, or at any other time, protoplasm has been led through the long chain of upward progress to a creature which would in any way resemble man.

In the development of human culture with its inventions, art and industry, and its increasing recognition of social obligations, the same sort of environ-

mental factors which influenced our prehuman ancestors have played an easily forgotten but extremely important part. Every section of human history bears the unmistakable stamp of the geographic surroundings in which man progressed from primitive barbarism to the complex civilization of the twentieth century. Geologic factors are the warp without which the tapestry of human progress could never have been woven.

Each of the early civilizations had its location beneath clear skies in a region of variable climate where the summers were not too hot, nor the winters too cold, but in which there was sufficient variation from month to month to invigorate the individual and keep him mentally alert and bodily active. In the infancy of the human species climate rather than landscape served as the stimulus to provoke ingenuity and develop industry. As simple discoveries were made, such as the utilization of fire to keep the body warm, there followed the possibility of a cold-ward march of civilization. As the climatic pendulum swung back during the waning stages of the last great ice sheets and as man learned how to use available resources in his struggle for a comfortable existence, the lands north of 40° north latitude opened invitingly to him. In the general vicinity of that circle round the earth he has found an invigorating and variable climate which has served both as a challenge to his best ability and as a tonic to keep him mentally and physically at concert pitch. During the past six

thousand years, the time for which we have a written record of human achievement, the course of empire has taken its way northward as well as westward.

Presumably it was the climatic barrier which prevented the invasion of North America by such primitive members of the human family as Sinanthropus and the Neandertalers. Not until mankind had learned how to keep his body warm could the journey around the northern rim of the Pacific Ocean be accomplished. Nor could the trans-oceanic routes in the warm temperate zone be used until man, a land animal, had discovered ways and means by which he could navigate the sea.

A log drifting down a river, or the floating carcass of a dead animal must have suggested to the savage mind a means of transportation down or across the stream. How long it was before someone bound several logs together to make a raft, or how many times the invention of the raft was made and then forgotten, will never be known. Building up its sides to keep waves from splashing on its surface led by easy stages to the construction of boats. The art of navigation was thus first attempted on the rivers and inland lakes; among many tribes it has never advanced beyond that infant stage. But given the right geographic environment, man has never failed to attempt the conquest of the open ocean.

The Caucasian race, for example, found in the inclosed or marginal seas of the eastern Mediterranean a nursery in which were taken the first feeble steps

toward marine navigation. Success in that limited environment was followed by the opportunity to pass into the kindergarten of the open Mediterranean. With sharpened wits and strong hearts resulting from the lessons learned in that kindergarten, the white races were ready a little later to embark along the shores of the eastern Atlantic, and in the training school afforded by its embayments, coastwise navigation was perfected. Ere long, intrepid navigators matriculated in the college of the open Atlantic; and today their successors pursue post-graduate courses in the University of the World Ocean. Again, the story of life development is phrased in terms of capable individuals presented with opportunities inherent in particular environments. Had the outlines of all the continents been like those of Africa, one can but wonder if giant ocean liners would have been a product of the twentieth century or whether they must have awaited some far distant future time.

If geologic factors have thus directed the development of life and are largely responsible not only for the coming of mankind but for its present state of progress, there is no escape from the conclusion that the future history of man will likewise be under the sway of environmental factors. As in the past, so in the present and the future, Mother Earth opens the door of opportunity and awaits with eager expectancy the response which her offspring will make. Ability to respond is largely a matter of inheritance, and man is in a peculiarly fortunate position there.

In his ancestral lineage there is no creature which when tried in the balance was found wanting. In human germ plasm there is no tainted heritage from Nature's derelicts. We have an ancestry of which we may well be proud. It yet remains to be seen whether we shall be equally proud of our posterity and they of us.

Chapter 8

The Outlook for the Future

"I like a road that wanders straight;
the King's highway is fair,
And lovely are the sheltered lanes
that take you here and
there;
But best of all I love a road that
leads to God knows where."

CHARLES HANSON TOWNE IN
THE BEST ROAD OF ALL

As a rule, prophets do not long retain what little honor they may temporarily possess, especially when they make bold to prophesy concerning physical events in the future history of the world. Yet when one turns from the long perspective of the past to the forecast of the future, he is provided with the only key which has thus far proved trustworthy for unlocking the secrets of the years that are to be. Knowledge of the recorded history of the earth, of animals and of man, supplies the basis on which an intelligent forecast concerning the events of tomorrow may be established. Experience indicates that the trend of events persists from the known past into the predict-

able future. As the twig is bent, so the tree is inclined.

On this principle it is worth while to enquire concerning the lapse of time during which the earth may be expected to continue as a suitable abode for man. The only prognostications regarding the "end of the world," which have any real significance are those based on ideas concerning the origin of the earth and its juvenile history as a planet in the solar system. The modern book of Genesis is based upon a vast number of observable vestiges of creation, including the form, mass, distribution and motion of the several members of the solar family. Coupled with these objects of the astronomer's study are the features of the earth's structure and composition, which the geologist investigates. The results of investigations in these two fields of science have produced several theories regarding the origin of the solar system.

It is now generally agreed that a system of planets revolving around a sun like ours must have had a biparental origin. The time-honored Laplacian

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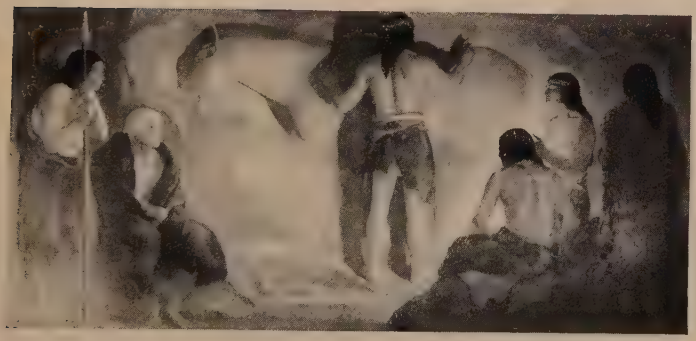
PLATE VIII: A. *In spite of their comparatively small brain capacity, the Neandertalers were successful hunters. Mr. John Norton, in this mural on display in the Logan Museum, Beloit College, Beloit, Wisconsin, represents an encounter between a group of individuals belonging to that extinct species of genus Homo and a herd of mammoths, also now extinct but formerly abundant in western Europe.*

B. *Another of Mr. Norton's murals shows several men of the Cro-Magnon race assembled in a cavern in the Dordogne region, while one of their number is engaged in the artistic venture of fashioning a bas-relief of a wild horse.*

A



B

Nebular Hypothesis, which pictures the condensation of a gigantic ball of gas with rings dropping from its bulged equator to form the individual planets, must be abandoned. Our solar system is not the result of simple cooling processes incident upon the old age of a dying star pursuing its pathway through the heavens in sublime isolation from other heavenly bodies. On the contrary, the peculiarities of mass and motion within it bespeak unmistakably the coöperation of two stars, the sun and some unknown wanderer through space, in the task of generating its planets.

The peculiarities of the solar system are emphasized by a description of the distribution of mass and momentum within it. The mass of the system is concentrated in the sun which weighs seven hundred times as much as all the planets together. But the momentum within the system is concentrated in the planets, which possess 97% of the total energy of motion found within the organization. This is the technical way of saying that the sun is huge and heavy, but rotates very slowly upon its axis, whereas the planets are small and light, but revolve very swiftly around the sun. To give the small planets their high velocity around a slowly rotating sun, there must have been some outside interference or disturbance.

Most scientists are now more or less in agreement about the nature of the disturbing event which long ago started the whole process of planetary evolution and made possible the organic evolution which

at present culminates in man. It is now believed that at a particular stage in the history of our sun, another great star, somewhat similar to it in temperature, composition and mass—and there are literally hundreds of millions of such bodies in space—passed by in fairly close proximity to it. If two such stars should collide, head on, the result would be a most unfortunate catastrophe; in all probability the entire substance of both stars would promptly be exploded into an extremely diffuse cloud of vapor which perhaps could never again organize itself into a star and certainly could not evolve into anything resembling our solar system. Probably some of the cloud-like nebulae which astronomers have discovered among the stars were formed by such a collision. But if the two stars passed by each other at a distance of one to ten billion miles, they would engage in what is technically known as dynamic encounter. That distance seems tremendous to all except astronomers who are accustomed to think in terms of dimensions well calculated to stagger the minds of most of us. Neptune, the outermost planet known prior to 1930 when "Pluto" was discovered, is a little more than two and three-fourths billion miles from the sun, and the nearest star is at present nearly nine thousand times as far from the sun as is Neptune.

Dynamic encounter between two stars occurs whenever they approach so close to each other that the internal gravity of either is equalized by the gravitative attraction of one star for the other. The sun,

an average star, is constantly subject to great explosions of gas in its outer envelope. These send bolts of incandescent vapor out into space like a fountain of water playing up into the air. Normally, the internal gravity of the sun is adequate to prevent the escape of the fiery gaseous projectiles and after hurtling out a few hundred thousand miles from the sun's surface they fall back again. When, however, the disturbing star was in the offing, its gravitative pull neutralized the restraining power of the sun, drew the gaseous bolts still farther from their source and gave them sufficient transverse velocity so that when they fell back toward the sun they missed it and went into elliptical orbits whirling around the sun from whence they had come. Permit less than a half of one percent of the sun's mass to be thus exploded and drawn into the space around it, and there would be more than enough material from which to organize the planetary family. This material would have great angular momentum or high velocity of revolution, regardless of the rotational velocity of the sun, and therefore would constitute an excellent starting point for the construction of a solar system such as ours.

Thus far, astronomers and geologists are in rather close agreement with respect to the origin of the earth and its sister planets, but from this point forward there are notable differences of opinion. One explanation of the process by which the chaotic nebula resulting from dynamic encounter was changed into the orderly cosmos of today has been proposed

by T. C. Chamberlin and F. R. Moulton, American geologists and astronomers. According to them, the materials exploded from the sun were sprayed out like gigantic fountains, each separate drop in the spray promptly congealing and thus creating a cloud of small solid particles—planet dust—enveloping the sun, around which each particle moved in its own elliptical orbit. Because the particles were small and had the motion of planets they are known as "planetesimals," and the theory involving them is called the Planetesimal Hypothesis. Under this view, the larger individuals in the haze of fragments would promptly begin to grow. As they swept through the dust-flecked space around the sun they overtook or were overtaken by other planetesimals, which would then be added to their surfaces and increase their size. This process of growth by accretion is still continuing. The meteorites which reach the earth each year are the last of the planetesimals which remain in the area, now almost completely cleared of débris, around the sun. On this basis, any "original crust" which the infant earth may have ever possessed is today buried beneath two thousand miles or so of foreign material gathered during the youth of the now mature earth.

An alternative hypothesis has been lately proposed by James Jeans and Harold Jeffreys, eminent British astronomers and geophysicists. The idea of dynamic encounter was first elaborated by Chamberlin and Moulton, and the new contribution is in reality a modification of the older view. The British scientists

suggest that instead of the fountain-like spray of discontinuous particles of gas, a huge continuous filament of incandescent vapor was drawn out by the disturbing star, like a high tide, and similarly given notable angular momentum. The unstable filament promptly broke up into eight large and many small portions, each of which condensed into a liquid sphere, then froze at its surface to form a solid crust, and finally cooled until it became solid to great depths. According to this theory, the earth sprang full-grown from the sun and has been cooling, condensing and shrinking ever since. Addition of material to the earth by accretion—as illustrated by the infall of meteorites—is believed to be a trivial contribution to its mass.

At the present moment, it is difficult if not impossible to place the balance of scientific opinion in favor of one or the other of these alternative explanations. But, fortunately, for our present enquiry it is quite immaterial which of the two processes was followed. The probability is that the actual truth lies somewhere between the two hypotheses. Just now we are vitally interested in knowing the nature of the episode which started the history of the earth; less important is knowledge of the details of procedure immediately after that event.

What happened in the past may of course happen again in the future. There is some reason for believing that at the time of its dynamic and dramatic encounter with another star, the sun already had a

family of planets in its train. If that earlier generation of planets actually existed, it was destroyed during the birth pangs of the new and present system. Similarly, when another such encounter occurs at some distant future date, the present family of planets will thereby be destroyed. But from that destructive catastrophe will come a new and perhaps better solar system than our own. We are dealing here, as so often in scientific investigations, with events which occur in cycles. There is no evidence of any real beginning, no prospect of an actual end. The entire life history of the earth is a mere incident in the inconceivably longer history of the sun. There is no reason for assuming that our sun is the only one in the stellar galaxy that has had some sort of dynamic encounter with another star. The precise details of this particular encounter may never be repeated, but something of the same nature may have happened over and over again in the past history of the universe and may happen repeatedly in the future.

The important question therefore is, how long does it take such a cycle of solar evolution to run its course, what is the interval of time between these catastrophic encounters which are so destructive and also so constructive in their results? According to the best data now available, the earth and its fellow planets in the solar system began their independent history at least two billion years ago. Since that time they have pursued the even tenor of their planetary ways without any significant disturbance from any

body outside the solar system. As we scan the heavens to ascertain when and where the next near-collision with another star will occur, we must conclude that there is no likelihood that such an event will take place before many hundreds of millions of years are added to the life of the earth. The nearest star, in the direction toward which the sun is moving, is so far away that it will require scores of millions of years for us to get where it now is, even at the high rate of speed which marks the passage of the solar system through space. And by the time we get there, that star will have travelled far, far away. It is quite impossible at present to chart the paths of the stars and announce when or where a dynamic encounter is scheduled to occur. We do not even know which one of the millions of stars in the galaxy to which our sun is confined should be charged with the responsibility of aiding in the birth of the earth. It has long since wandered far upon its careless way and is now lost among the crowd, utterly regardless of the consequences of its casual deed.

But this we can say with certainty: dynamic encounter with another star cannot occur within several hundred million years from the present time. Although philosophically it is of prime importance to face the fact that the entire history of the earth is a local and temporary affair, practically man need take no thought concerning the smash-up which will some day terminate life upon the earth. We may set aside from our present consideration any external dis-

turbance as likely to limit within a reasonable interval the fitness of the earth as an abode for man.

But what about conditions within the solar system? Is the sun energetic enough and reliable enough to provide us with sufficient heat for hundreds of millions of years to come? Life, as we know it, can persist only within a very narrow range of temperature. Raise the temperature of the earth's surface everywhere to the boiling point of water or depress it everywhere below the freezing point, and life upon the earth must very shortly become extinct. Perhaps for a time man could artificially cool or warm a portion of his surroundings sufficiently to carry on, but it would be a losing fight. Eventually, he would succumb.

Never since the beginning of the Paleozoic Era, six hundred million years ago, and probably for a long time before that, as well, have conditions at the earth's surface been sufficiently unfavorable to cause a break in the continuity of living beings. The stream of life has pulsated, now swiftly, now slowly, but never has it ceased to flow. Through all the years, the energy output from the sun has been sufficiently uniform to maintain upon the earth the peculiar environment essential to vital processes.

Computations were made a generation ago which seemed to indicate that the sun's energy must soon be dissipated and that within a few score million years its output of heat would be inadequate to support life on the earth. But those computations were based upon

the physics of that day. The new physics tells a very different story. The sun is not simply a great storehouse of energy; it is a factory within which energy is actually created or at least is made available in radiant form by transformation from some other condition. There is now abundant reason for believing that the sun is capable of keeping the earth within the temperature limits necessary for maintaining life during many hundreds of millions of years to come.

At the same time, it is true that climatic fluctuations of no mean importance have occurred. Some of these have been distinctly inimical to life and have caused a notable reduction in the population of the earth. There have been many times when the middle and polar latitudes, both in the northern and southern hemispheres, have been buried beneath great mantles of glacial ice. The latest of these brought a frigid climate into the northern states only forty thousand years ago. The existing ice caps on Antarctica and Greenland are but the slightly diminished remnants of former more extensive ice sheets which were present on those two continents during the Great Ice Age. The glaciers in Alaska, in the Rocky Mountains of Canada, in the Alps and the Himalayas are the dwindled remnants of formerly extensive glaciers that spread from the mountain fastnesses out upon the surrounding plateaus and plains. We are still in the waning stages of the latest glacial episode.

Recalling that during this Pleistocene ice age there were five advances and retreats of the ice, with

interglacial intervals between each two glacial stages, it is quite pertinent to raise the query, are we living today in an interglacial epoch, with the expectation that ere long great masses of ice will come from the heights of Labrador and Scandinavia to render the Dominion of Canada, the northern states, and northern Europe unfit for human abode? None of us can give a definite answer to that question. The evidence is more or less conflicting. In the last few decades most of the glaciers of the Alps and Alaska have been retreating, suggesting greater warmth, and many persons believe that the weather during modern winters is not so severe as it was during the days of their childhood. As a matter of fact the official records do not always bear out the impression which the weather prophets of some particular localities would like to give. No significant change in the direction of greater warmth is recorded by instrumental observations during the last sixty or seventy years. Nevertheless the recession of the glaciers suggests the further disappearance of glacial conditions in the immediate future.

On the contrary, there are certain facts, such as those pertaining to the coral islands, which suggest an opposite trend. Dr. J. Stanley Gardiner, for example, cites evidence which leads him to believe that the warm waters of the tropical zone in the Pacific Ocean are becoming chilled, as the colder waters expand equatorward from the poles. In consequence, the belt in which corals, restricted to a very temperate zone,

can live is being narrowed. If this is true, it would indicate that in the last three thousand years there has been a slight change from warmer toward present colder conditions.

But if, twenty or fifty thousand years from now, vast ice sheets should once more begin to form, as indeed they may, it would not be a terrible catastrophe. The total number of square miles of land available for human occupation might be reduced by as much as one-third, but genus Homo has weathered at least two great glacial advances. It is probably safe to assume that man in the year 25,000 A.D. will be better able to adapt himself to glacial climates and conditions than was man in the year 50,000 B.C. However, the possible restriction of lands suitable for human occupation is a significant factor which may be of great importance to the future development of man upon the earth.

At the present time the climate of the earth is probably not quite normal. It is still a subglacial climate, rather than the type characteristic of most of geologic time. Our records indicate that throughout much of earth history there were long intervals of genial, equable climate, times during which corals and palms could live within what is now the Arctic circle, times when there was no such sharp demarcation into climatic zones as there is today. The intervals of great climatic differentiation, in one of which we now find ourselves, were frequently repeated, but were of comparatively short duration.

If before long, a few hundred thousand years perhaps, the Great Ice Age is truly a thing of the past, we may anticipate a return to non-glacial conditions with much more even distribution of temperature upon the earth. In consequence, the area available for occupation by humankind would be greatly enlarged. But offsetting this optimistic outlook is another fact. As a rule, when the surface of the earth was marked by evenly distributed temperatures, the lands were low and the seas were broad. At those times, the mountain barriers were few and low; vast marine embayments spread into the interior of the continents and thereby reduced the area of dry land available as an abode for terrestrial creatures. In other words, regardless of the precise details of the future changes in the surface and the climate of the earth, we cannot expect any large expansion of the territory on which man can dwell or any notable increase in the natural resources which will be available for him to use.

Such is the significant conclusion resulting from our study of physical conditions. We belong to a species of animal which is placed in a particular and limited environment: so many square miles of land, so many tons of various metals and fuels, so much energy available. Although our offspring may enjoy it for what seems to us an inconceivably long period in the future, nevertheless it is at best a limited environment. Its resources are many and of them man is in a very real sense the custodian. Each generation is temporarily the steward responsible to all posterity

for an accounting of the use to which they are put. With the prospect of a long future in which the earth will remain suitable as an abode for man, we may well ask the question: what will we and our offspring do with this opportunity?

It is probably unwise and certainly unnecessary for us to worry about the future, millions of years hence. Conditions which will then prevail upon the earth, and the nature of our remote posterity, are impossible to predict. If humanity charts its course as wisely as possible for the next five or ten thousand years, it will have done all that can reasonably be expected. This of course is much more than most people have done. Even our most "forward-looking citizens" rarely project their thoughts more than two or three hundred years into the future. Yet it is what the modern man ought to have in mind as he constructs his individual philosophy and determines his attitude toward the world about him.

The probable trend of human history during the next ten thousand years can be intelligently considered only in the light of the past development of the race. During the twenty-five thousand years immediately preceding the Christian era, the existing species of humankind multiplied rapidly and populated the entire face of the earth. During that time, man penetrated every quarter of every continent except Antarctica. He went into mountain valleys, up onto high, bleak, wind-swept plateaus, into oases of the desert, among the tropical jungles. In every conceiv-

able terrestrial environment except the absolutely barren cold or dry localities, man adapted himself to local conditions. In consequence, the human species was differentiated into many races and subdivisions of races. During that twenty-five thousand years, man was undergoing a provincial type of evolution. In the last five hundred years all that has changed. Modern methods of transportation, the present demand for new materials, and the well-nigh universal desire for imperial expansion have taken us swiftly from continent to continent. Barriers of mountain and sea and climatic zone have been levelled; the world has been transformed into a neighborhood. We are today nearing the high-water mark of the wave which is sweeping mankind from the provincialism of the past into the cosmopolitanism of the future. The same principles which controlled the evolution of the marine invertebrates in Paleozoic time, as they shifted from provincialism to cosmopolitanism, will apply to mankind.

In these same few thousand years the earth's human population has increased rapidly in number. At first there was a vast area of uninhabited territory with an abundance of raw materials and many sources of food. Expansional evolution was the rule, and almost any type of racial idiosyncrasy or vagary could find a place for itself. But we are standing today at a particularly important milestone in human history. The vacant spaces of the earth are rapidly becoming occupied; Uncle Sam is no longer "rich enough to

give every man a farm." The present population of the earth is slightly in excess of one and three-quarter billion souls, or an average of about thirty-four persons to each square mile of land. The distribution of population is of course very uneven; in the United States there are about forty persons to the square mile, in England nearly seven hundred, in the Commonwealth of Australia only two. At many places the population is already at the saturation point; just as many persons find sustenance as can possibly do so. If the number of individuals increases, some have to emigrate in search of a place where there is room for them to live. At most localities, however, the saturation point has not yet been reached and for a time the population may safely expand. But there is of necessity a limit to the capacity of the earth to support human life, and that limit is almost within sight.

The earth's population capacity is primarily determined by its available agricultural resources. When, in that far-off Pre-Cambrian stage in earth history, certain of the primordial unicellular creatures which constituted the entire organic world lost the chlorophyl which enabled them to utilize directly the energy of the sunlight and to manufacture food for themselves, a handicap was placed upon the entire animal kingdom. From that yoke man cannot free himself. He is, and always will continue to be, dependent upon plants for food. Heredity and environment condemn him forever "to till the ground from whence he was taken." Robert R. Kuczynski, of the

Brookings Institution, has recently surveyed the situation and reaches the conclusion that the earth's area of tillable soil limits the future population of the world to something like ten billion persons. This is probably as close an approximation to the truth as can be made at the present time.

The population of the earth has doubled in the last seventy-five years, within the memory of many individuals now living. According to the most recent estimates of the International Statistical Institute, the population between 1920 and 1926 increased at an average annual rate of five-eighths of one percent, a rate which would again double the world's population in one hundred and ten years and cause it to reach the theoretical maximum of ten billion in about three hundred years. But this rate of population increase will not continue. Already, large sections of humankind are failing to produce offspring at a rate adequate even to maintain a stationary population total. The supply of children in France in 1927 was nine percent less than the number required to preserve the present figure for the population of that republic; in England and Wales the similar deficiency was about eighteen percent. In both these countries, there is recognition, conscious or unconscious, of the fact that the expansional phase of human development is even now giving place to the restrictional phase.

These are the two major trends in human evolution: from provincialism to cosmopolitanism, and from expansional tendencies to restrictional influ-

ences. For us, as for the Paleozoic invertebrates, the experiments that have been tried in the past are now being placed in the balances and tested. Many of them will doubtless prove wanting; but some will meet the demands of Mother Earth. The new conditions will also require new methods; the new problems cannot be solved by the old principles.

Apparently there are only two courses for man as he faces the next few hundred years. He can engage in interracial or international competition, killing millions of people to keep down the total population, or he can engage in interracial and international coöperation, utilizing all available natural resources and raw materials to make life as worth while as possible for the maximum number of human beings. Which of the two courses is it more likely that he will grasp? Both have been tried in the last few decades and both may be tried again. But from the longer perspective of the geologic past, on which can we expect the emphasis to be placed?

The scales which Mother Earth has used to measure the fitness of her offspring have not always been the same. Survival value, and, more important still, progress value have been phrased in different terms at different times. Once it was ability to use a modified swimming bladder as an accessory breathing apparatus. Again, it was ability to steal silently through the underbrush and leap lithely upon an unsuspecting three-toed horse. But often it was mentality rather than physical prowess. At several important mile-

stones along the path of life the rivalry was between unintelligent powerful brutes and more intelligent but less powerful creatures. There was for example the dramatic episode near the end of the Mesozoic Era when the dinosaurs were blotted off the face of the earth and the placental mammals were selected to carry on the torch of progress. Then, and at many other times, the palm of victory was awarded to wits rather than weight, to brains rather than brawn. Especially significant is the emphasis upon improvement in mental ability, which has characterized each step along the pathway that leads to man. Because the sum total of his environment has favored brains and mentality, man is today in his present position of obvious power.

Furthermore, the pages of Mother Earth's diary record unmistakably a gradual emergence of the spirit of coöperation. There is no such thing as family life among most of the lower animals. Probably the trilobites were gregarious, but they were exceptions to the general run of Cambrian creatures. On the other hand, the mammals almost universally care for their offspring and associate together in herds or droves or packs. Especially in the strain that led to man has the emphasis been placed upon the widening spread and deepening hold of habits of coöperation. Ideals of brotherliness must have been deeply ingrained in the days when our prehuman ancestors first ventured down upon the ground from the comparative safety of the tree-tops to engage in competition there with

the more agile, and individually more powerful, carnivorous beasts of the time. More lately the earth has witnessed the banding together of families into clans, of clans into tribes, of tribes into nations; and today some of us dare dream of a federation of the world, a parliament of man. Gradually the area within which the individual is interested in every other individual has enlarged. There is that in the environment which places greater value upon the welfare of society than upon the welfare of the individual if that be antagonistic to the other. Social comity has emerged as a powerful directing force because of the nature of the world to which we belong. And social comity is a highly valuable ideal, regardless of whether we call it simply the "higher selfishness" or label it more grandly as "unselfishness."

This same tendency is recognizable in other species as well as in man. In all probability the social organization of certain insects—presumably the offspring of the trilobites—is, for the group, superior to any society which man has thus far been able to establish. The social insects represent the finest achievement to date among the invertebrates along the lines of intelligence and coöperation, but they must not be taken as establishing an ideal toward which man should strive. In the insect society, individuality is sacrificed for the good of the group; no insect, except it be the queen bee or her equivalent in other species, is recognized as having any value in itself. "One for all" seems to be the whole of the insect slogan. But

man has embarked upon a different course. His experiment seems to be inspired by the hope that individuality may be retained at the same time that it contributes effectively to the welfare of the entire group. The value of personality is believed to be too great to justify its sacrifice even to gain social comity. To the slogan "one for all," man adds its complement, "all for one."

The human experiment is far more difficult of accomplishment than that of the insects. Perhaps that is one reason why human development is geologically later than insect progress. To solve the problems which man faces as the tide turns from provincialism to cosmopolitanism, to discover ways and means for effective coöperation without loss of individual independence, mankind must lay hold on every available resource. Some resources are within, our heritage; others are outside of man, our environment. Of some we are already aware; of others, we have as yet no knowledge whatsoever.

In the past, successful advances along the path of life were made by a small minority of individuals, here and there, who capitalized to the full the innate ability with which they were endowed and grasped every opportunity offered by their environment. In each case, they strove to accomplish that which never before had been achieved. If man sets as his goal merely long-continued existence on the present level, then he should try to be true to himself, to express more completely his own personality, to be as efficient

a man as possible. But if he wishes to hand on the torch of evolutionary progress to a posterity better than he, if he desires to participate in the upward as well as the onward march of living beings, then he must have as his aim something that has never yet been realized, accomplishments that he himself has not yet been able to complete. Such is the essential characteristic of all the successful groups of animals and plants throughout the history of the earth.

The ideal of social service, of the brotherhood of man, is being deeply impressed upon the mind of man because of the transition from expansional to restrictional evolution within the limited environment provided by the earth. Many of our social and spiritual ideals are in the last analysis imposed upon us by the sum total of environmental factors with which we are surrounded. Yet man is not merely a victim of geologic circumstances, though he is unquestionably a product thereof. He bears witness to the emergence in time and space of a new sort of creative ability. He may select from several possible goals the particular one toward which he will strive to go. Within limits, he is able to determine his own course of action.

This is partly due to the unique relationship which now exists between man and his environment. Most animals have succeeded by adapting themselves to their physical surroundings; each has specialized for some particular type of environment. But man is a specialist in adaptability rather than in adaptation. His generalized body permits him to live under an

unusually wide range of circumstances. Moreover, his ingenious mind and facile hand enable him to transform his environment to suit his wishes. When the agriculturalist invaded New England in Colonial days, he stripped the trees from the forested hillsides to establish his farming communities. On the treeless plains of Nebraska the farmer plants trees for a windbreak along his fields or for shade beside his farmstead. Man drains the marshes and irrigates the desert, tunnels the mountains and bridges the rivers. Constantly he has been molding the landscape nearer to his heart's desire. Because of these abilities, uniquely developed in mankind, the sharp goad with which environment has directed the activities of other animals has for him been blunted. Whereas environment is in direct and immediate control of the destiny of most animals, man has broken its chains and enlarged the area of his own freedom. The boundaries within which the earth confines each of its offspring are far greater for man than for any other creature.

The responsibility which rests upon man is proportional to the ability which he possesses and the opportunity which he faces. Perhaps that responsibility is no greater for him than was that of Notharctus or Eohippus or a trilobite, each in his own day, but because of man's unique abilities it is the greatest responsibility that has ever rested upon any of the earth's offspring.

In the past, evolution, influenced and directed by the environmental forces inherent in the earth,

has proved itself progressive. At each crisis, a minority somewhere has responded to the challenge of the moment. As we face the future, there is in consequence abundant reason for an optimistic outlook. Somewhere among the sons of the earth are individuals ready, willing and able to respond to the challenge of today and tomorrow. They are a small minority, struggling against the overburden of a complacent and conservative majority; but similar minorities have been victorious before and will be victorious again. Although the evolutionary processes do not guarantee progress, the fact that progress has resulted from them is abundant ground for the faith that better things are yet to be.

From which of the four great races of mankind or from which country will come the most important contribution to the welfare of the future population of the earth is a question yet unanswerable. It is quite likely that in the melting pot which is every continent there will be a contribution from each race and from many subdivisions thereof. It is the responsibility of people who pride themselves upon their splendid ancestry and who are rightly proud of their own accomplishments to make as large and valuable a contribution as possible. If they face the next ten thousand years with intelligence, courage and high purpose, they will find the resources which they need and will become still more worthy scions of Mother Earth.

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INDEX

Accessory breathing organ, 49
Acheulian artifacts, 151, 162
Advent of mammals, 33
Age of fishes, 33
Age of invertebrates, 33
Age of mammals, 74
Age of mankind, 33, 101, 129
Age of reptiles, 33, 59, 80
Algæ, 43
Alpha rays, 13
Alps, 12
Altamira, Spain, 166
Amphibians, 29, 49, 54
Andrews, Roy Chapman, 60
Antevs, Ernst, 21
Anthropoid apes, 42, 85
Anthropoidea, 37, 84
Anticline, 6
Antiquity of man in America, 174, 198
Appalachian Mountains, 6, 11, 32
Aquatic reptiles, 65
Archeozoic Era, 30, 33
Art of navigation, 236
Artifacts, 34
Attainment of upright posture, 230
Aurignacian artifacts, 153, 160
Ausable Chasm, 5, 6
Australoid race, 192
Australopithecus, 95

Baboon, 85
Badlands, 79
Basket-makers, 185
Belief in the continuity of life after death, 169
Beta rays, 13
Black, Davidson, 125
Box Canyon, Ouray, Colo., 9
Brachiation, 97, 138

Cambrian invertebrates, 44
Canadian Rocky Mountains, 6
Capuchin, 85
Carboniferous Period, 56
Carnivorous dinosaurs, 62
Case, E. C., 223
Catarrhine anthropoids, 85
Caucasian race, 192, 236
Cave men, 146
Cenozoic Era, 30, 74
Chamberlin, T. C., 244
Chellean artifacts, 150, 162
Chimpanzee, 85
Chlorophyl, 211
Chou Kou Tien, China, 123
Classification of living creatures, 36
Clawed carnivores, 42
Cliffdwellers, 181
Cliff Palace, 182
Climatic fluctuations, 249
Climatic zones, 251
Coast of Scotland, 7, 8
Cold-ward march of civilization, 235
Colorado, Mitchell County, Texas, 201
Condylarths, 81
Connecticut Valley, 17, 19
Conquest of the open ocean, 236
Continuity of the stream of life, 39
Core implements, 151
Correlation of glacial stages in North America and Europe, 107
Cosmopolitan faunas, 218
Cradle of the human race, 190
Creodonts, 80
Cretaceous Period, 61
Cro-Magnon man, 133, 159, 208
Crustal movements, 11
Cueva del Mas d'en Josef, Spain, 166

Cycle of solar evolution, 246

Dawn of human intelligence, 129
Dawson, Charles, 109
de Chardin, P. Teilhard, 127
Dependence of animal kingdom upon plants, 212
Development of the brain, 135
Devonian fishes, 48
Devonian Period, 48, 219
Dinosaurs, 58, 80
Distinction between plant and animal kingdoms, 211
Distribution of temperature upon the earth, 252
Don Valley, Ontario, 22, 195
Dordogne region, 145
Douglas, A. E., 184
Dryopithecus, 93
Dubois, Eugene, 117
Dynamic encounter, 242

Early civilizations, 235
Earlier generation of planets, 246
Egg-laying mammals, 40
Emergence of air-breathing quadrupeds, 219
Environment of North American vertebrates in the late Paleozoic, 223
Environmental changes, 233
Eoanthropus dawsoni, 113, 115, 208
Eocene primates, 85
Eohippus, 83
Eoliths, 97, 140
Europe during the Pleistocene glacial period, 103
Evolution of the reptiles, 223
Evolutionary processes, 66
Evolution of the hand, 136
Evolution of the human foot, 99
Evolution of the human head, 88
Expansional evolution, 215

Fayum, Egypt, 92
First fishes, 48
First living creatures, 211
Fisher Mounds, 178
Flake implements, 152
Flying reptiles, 62, 63
Folded strata, 7
Folsum, Union County, New Mexico, 201
Font-de-Gaume, Dordogne, France, 166
Fossils, 25
Frederick, Oklahoma, 202
Future population of the world, 256

Gamma rays, 13
Gardiner, J. Stanley, 250
Genus homo, 37
Geological timepiece, 13
Geological timetable, 30
Gibbon, 85, 98
Glacial chronology, 21
Glacial Man in America, 174
Glaciers, 18
Gorilla, 85, 98
Grand Canyon of the Colorado River, 6, 16, 74
Great Ice Age, 17, 18, 24, 33, 102, 160
Green River basin, Wyoming and Colorado, 17
Green River formation, 48
Günz glacial stage, 106, 162

Hackensack Meadows, New Jersey, 19
Hammer-stone, 149
Harbors of refuge, 215
Hartford, Connecticut, 21
Heaven's Fold, Montana, 7
Heidelberg man, 131
Helium, 14
Herbivorous dinosaurs, 58, 59
Hesperopithecus, 90
Himalaya Mountains, 231
Hominidæ, 37, 85
Homo heidelbergensis, 129
Homo neandertalensis, 131, 153, 208
Homo sapiens, 37, 132
Hoofed herbivores, 42

Ice sheets, 19
Ichthyosaurs, 27, 66, 80
Illinoian glacial drift, 24
Iowan glacial drift, 24
Iowan-Wisconsin interglacial interval, 194

Isthmus of Panama, 89

Java ape-man, 120
Jeans, James, 244
Jeffreys, Harold, 244
Jurassic Period, 65

Kedung, Brubus, Java, 121
Kuczynski, Robert R., 255

Lake Geneva, Switzerland, 20
Land bridge between Asia and North America, 196
Laplacian Nebular Hypothesis, 240
Lapse of time, 12
Lemuroids, 42, 84
Lemurs, 83
Life on Mars, 233
Living creatures on other planets, 233
Limestone, 4
Lull, R. S., 222
Lung fishes, 49, 219

Magdalenian industry, 159, 161
Major trends in human evolution, 256
Mammalia, 37
Mammal-like reptiles, 70, 228
Man's place in nature, 39
Marine navigation, 237
Marmosets, 84
Marsupials, 172
Maya calendar, 187
Maya civilization, 186
Mesa Verde National Park, Colo., 181
Mesozoic Era, 30, 32, 52, 58, 62, 68
Mesozoic placental mammals, 72
Middle paleolithic culture, 162
Mindel glacial stage, 106, 162
Miocene Period, 230
Missing link, 46
Modification of fins, 52
Mongolia, 60, 72
Mongoloid race, 192
Montana Rockies, 7
Moulton, F. R., 244
Mound-builders, 176
Mounds near Newark, Ohio, 177
Mountain-making disturbances, 11
Mousterian artifacts, 152, 162
Mural drawings, 164

Neandertal man, 131
Nebraskan glacial drift, 25
Negroid race, 192
Neoliths, 140
New Stone Age, 140, 159
New World monkeys, 90
Notharctus, 86, 176

Oldest known bird, 63
Oldest known fossils, 43
Old Stone Age, 140
Old World Monkeys, 85
Oligocene rocks of northern Africa, 91
Orang-utan, 85
Ordovician Period, 44
Origin of the earth, 240
"Original crust" of the earth, 76
Origin of lungs, 51
Osborn, H. F., 90
Ostracoderms, 47
Overthrusting, 11

Paleolithic age, 144
Paleolithic art, 167
Paleolithic man, 163
Paleoliths, 140
Paleozoic amphibians, 56
Paleozoic Era, 30, 32
Parapithecus, 91
Peculiarities of the solar system, 241
Pei, W. C., 124
Pennsylvanian Period, 224
Pen-tailed tree shrew, 72
Percussion flaking, 149
Permo-Carboniferous glacial period, 228
Petrified skeletons, 26
Piltdown artifacts, 116
Piltdown man, 111, 191
Piltdown, Sussex, England, 109
Pithecanthropus brain, 121
Pithecanthropus erectus, 115, 208
Placental mammals, 37, 40, 41
Planetesimal Hypothesis, 244
Plant-animals, 38
Plant fossils, 29
Platyrrhine anthropoids, 84

Pleistocene Period, 33, 102, 108
Pleistocene record of mankind, 109
Plesiosaur paddles, 55
Plesiosaurs, 66
Pliocene anthropoids, 95
Pliopithecus, 92
Post-glacial chronology in Scandinavia, 21
Pre-Chellean artifacts, 149, 162
Present population of the earth, 255
Pressure-flaking, 155
Primates, 37, 42, 83
Primitive mammals, 70
Progressive evolution, 210
Progress value, 257
Propliopithecus, 92
Proterozoic Era, 30, 32
Provincial faunas, 217
Pterosaurs, 63
Pueblo Bonita, 184
Pueblo Indians, 179
Pyramid at Copan, 187

Quanta, 13
Quaternary Period, 76

Radio-active timekeepers, 14, 16
Radio-activity, 13
Radium, 14
Rate of population increase, 256
Recession of Niagara Falls, 21
Records of prehistoric man, 34
Rejects, 144
Relative age of the fossils, 29
Reptiles, 56
Restrictional evolution, 216
Rhodesian "man," 127
Rhodesia, South Africa, 127
Rhone River, 20
Riss glaciers, 106, 162
Rock shelters, 146
Rocky Mountains, 11, 12, 33

St. Johnsbury, Vermont, 21
St. Lawrence Valley, 22
Sandstone, 4
Scott, W. B., 204
Scyphanthropus, 127
Secondary Rocks, 76
Sedimentary rocks, 4
Sequence of events, 11, 12
Sequence of life, 29
Shale, 4
Sierra Nevada, 11
Simiidæ, 85
Sinanthropus pekinensis, 124, 176
Sivapithecus, 93
Siwalik Hills of India, 92
Social comity, 259
Social insects, 259
Solutrean artifacts, 155, 160
South America, 90
Species, definition of, 39
Spectral tarsier, 82, 84
Spirit of cooperation, 258
Stagnation in evolution, 224
Standards of success, 208
Survival value, 257

Taungs, South Africa, 95
Terminal moraine in New England, 23
Tertiary ancestors of mankind, 144
Tertiary mammals, 80
Tertiary mammals of Australia, 171
Tertiary Period, 74
Thorium, 13
Tree-ring chronology, 184
Tree-shrew of Borneo, 72
Trend of human history, 253
Trilobites, 44, 45
Trinil, Java, 117

Unconformity, 10
Unity of mankind, 190
Upper paleolithic industries, 159
Uranium, 13, 14

Value of personality, 260
Varves, 19, 48
Vero, Florida, 199
Vestiges of creation, 4
Viviparous Mammals, 37, 40

Walnut Canyon, Arizona, 185
Walpi, Arizona, 181
Wisconsin glacial drift, 24
"Wisdom" teeth, 87
Woodward, A. Smith, 109
Würm glacial stage, 106, 160, 162

Young, C. C., 126

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